Big Idea 4: Interactions

An overview of interactions at all levels of biological organization

Intramolecular Interactions –

Intermolecular Interactions –

Intracellular Interactions –

Intercellular Interactions –

Organ/System Interactions –

Population Interactions –

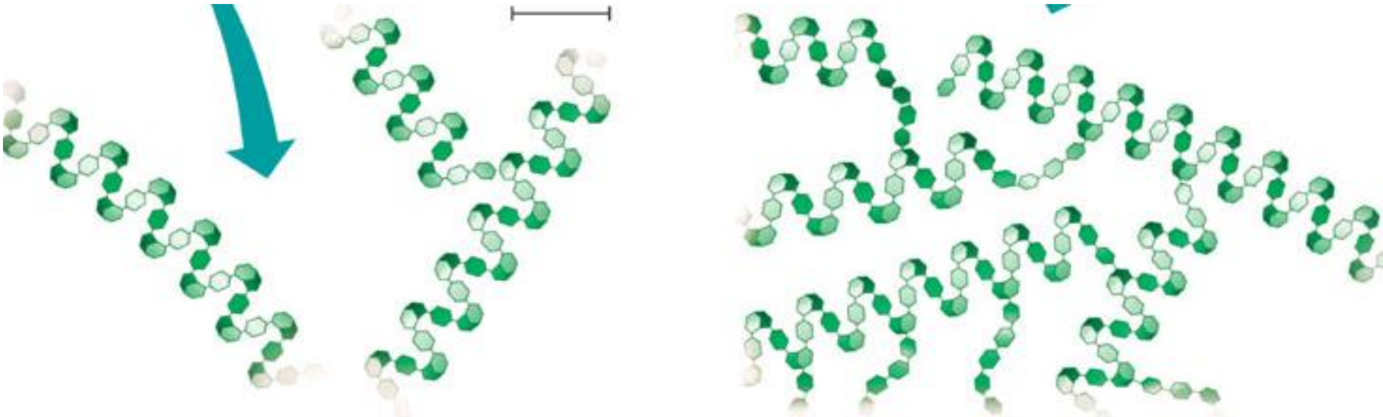
Community Interactions –

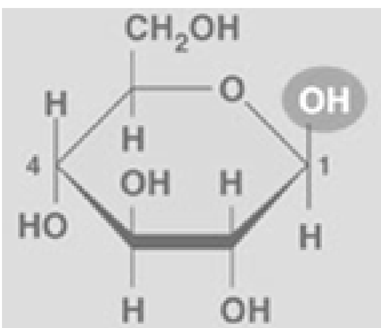
Ecosystem Interactions –

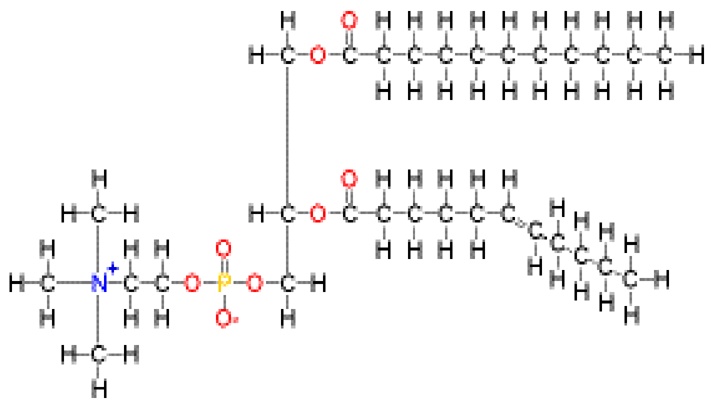
Intramolecular Interactions

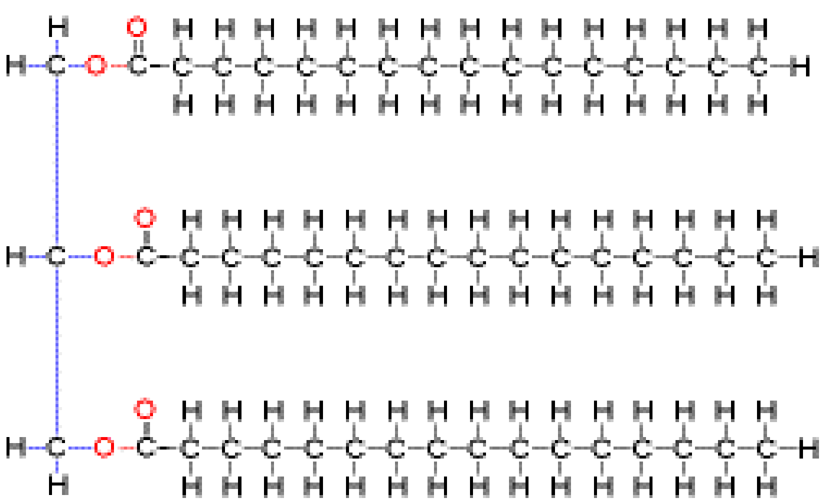
- Different atoms interact to form molecules
  - Carbon, Nitrogen, Phosphorous, Oxygen, Hydrogen, Sulfur
- Sequence & location of atoms are significant to their interactions & ultimate molecule structure & function.

Carbohydrates vs. Lipids:





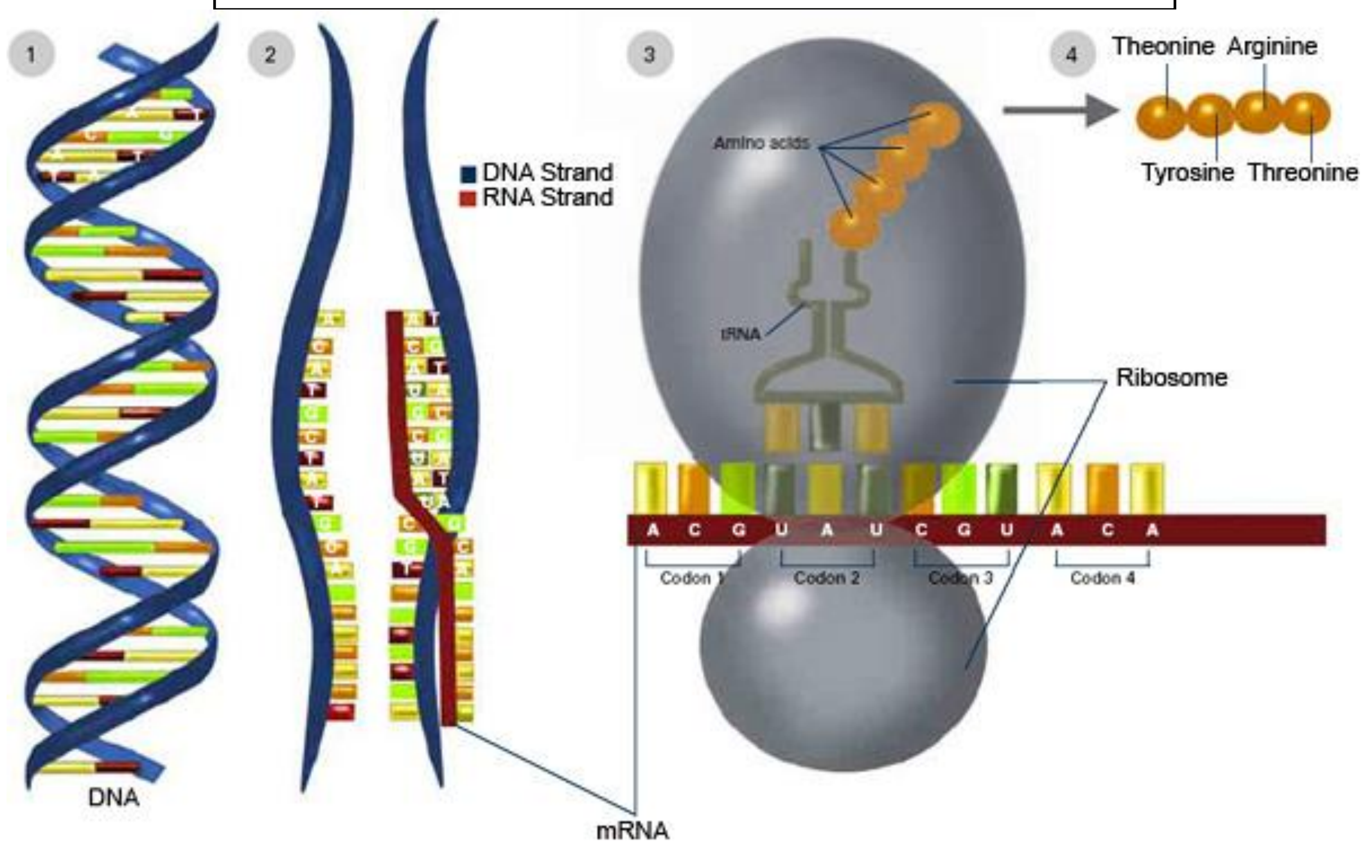




Intramolecular Interactions

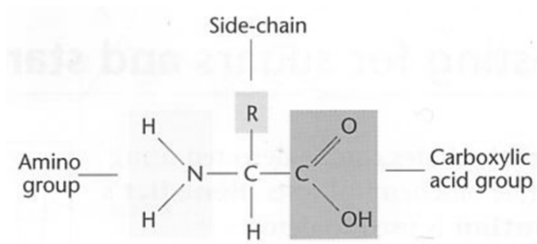
DNA vs. RNA:

Proteins vs. Nucleic Acids

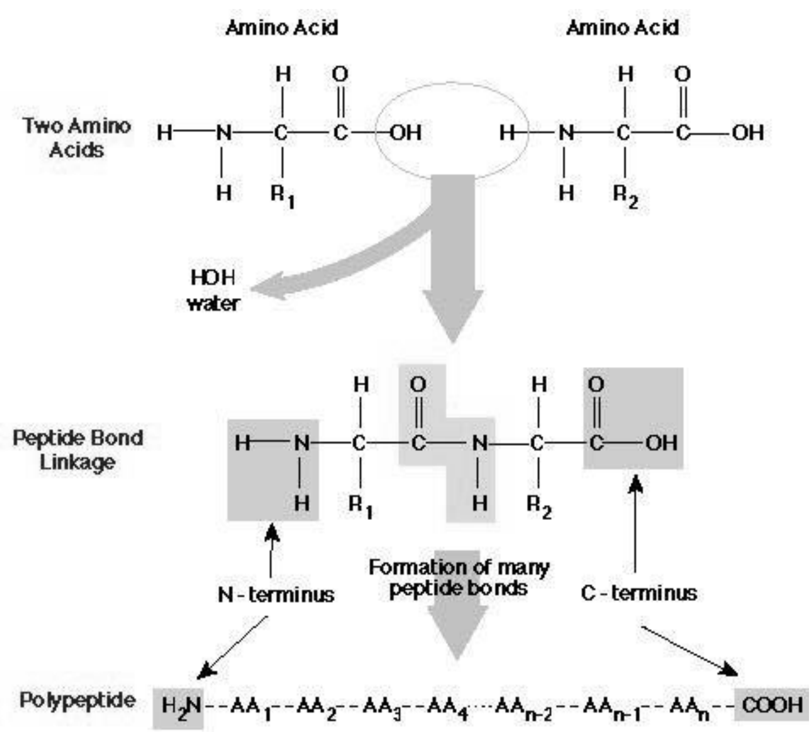


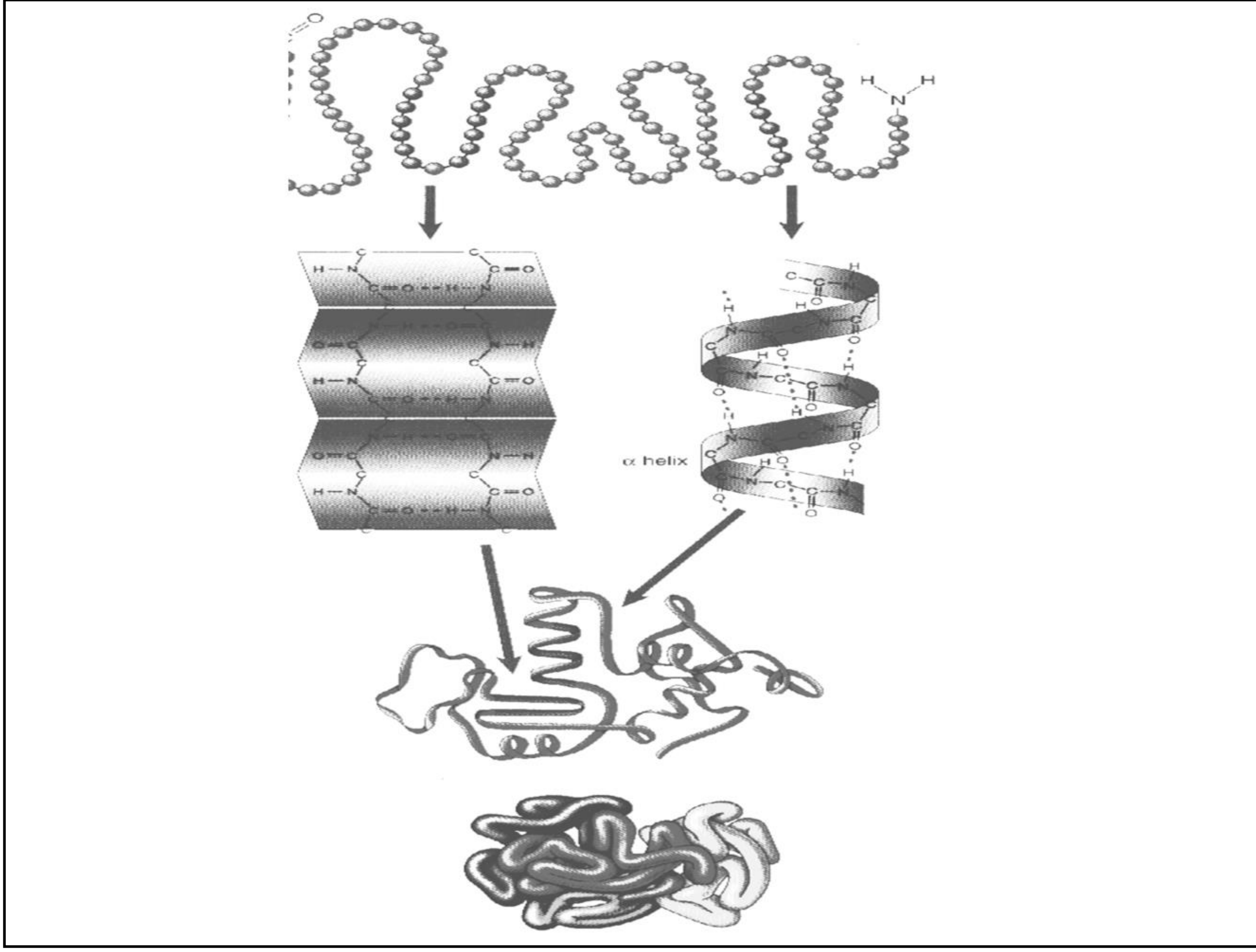
Proteins

- Amino acid interactions depend on structure
  - Hydrophilic, Hydrophobic, Ionic (R-Group)
- Sequence of amino acids leads to different functions & interaction capabilities.



Proteins: Directionality – NH_2 vs. COOH ends





Primary Structure

-Peptide bonds

-Linear sequence of AA's

Secondary Structure

- Hydrogen Bonds

- Twists & Folds of the sequence

Tertiary Structure

- R-Group interactions

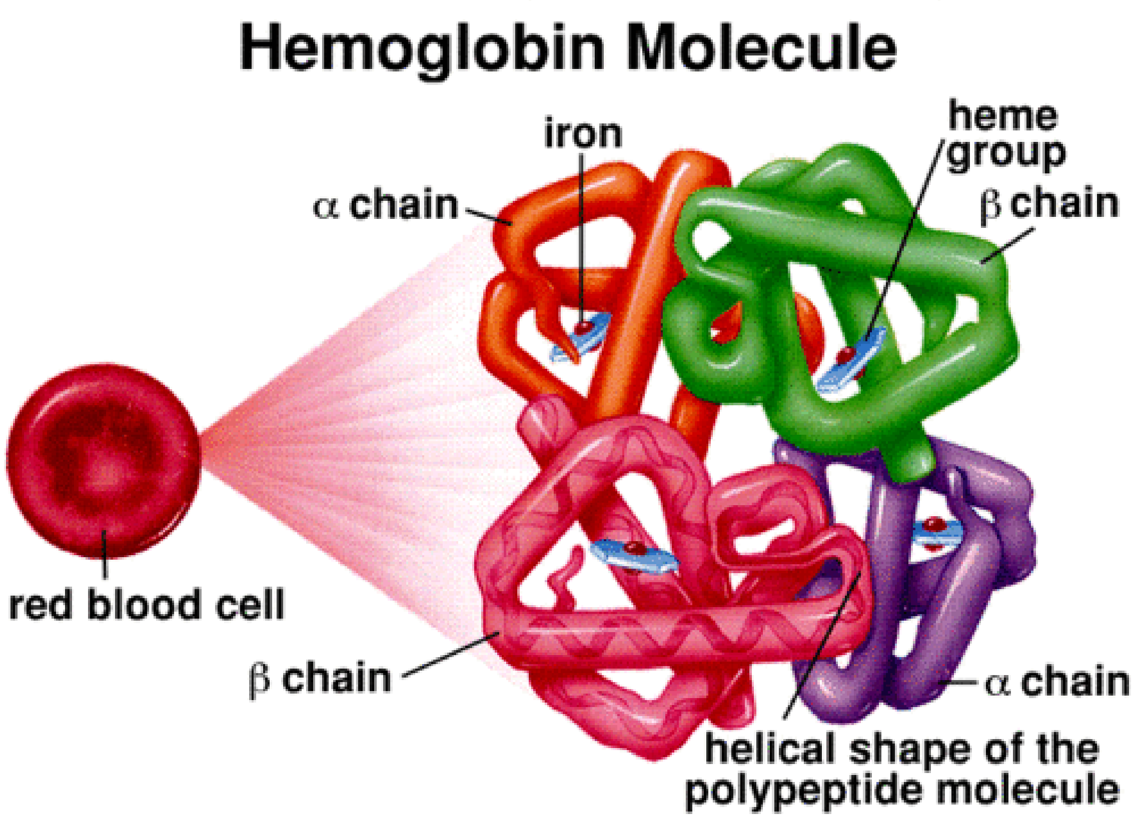
- ionic, hydrophobic, etc.

Quaternary Structure

- 2+ polypeptides interacting

Intermolecular Interactions

- DNA & RNA during transcription
- Enzymes & substrates during catalysis
- Hemoglobin & oxygen during gas exchange

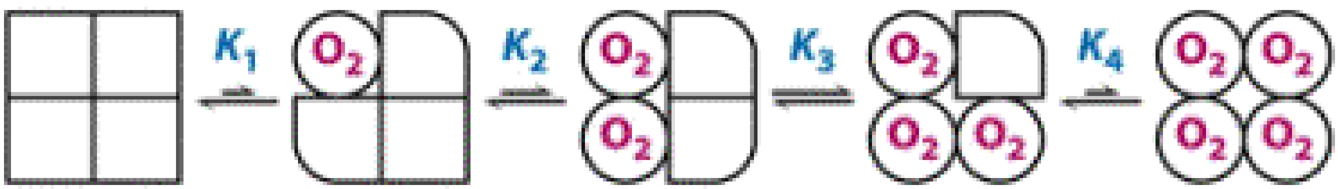


I. Model of Intermolecular Interactions - Oxygen transport

Hemoglobin (Hb)

binds oxygen in a ***cooperative*** fashion

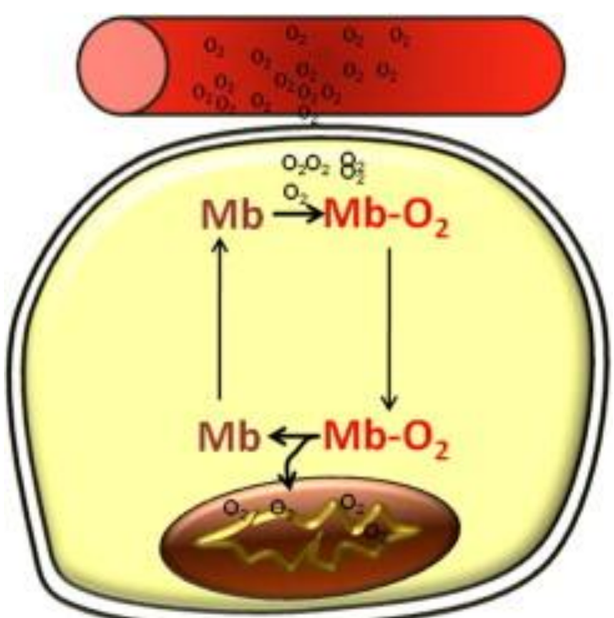
Transports & delivers O_2 to **all body tissues**

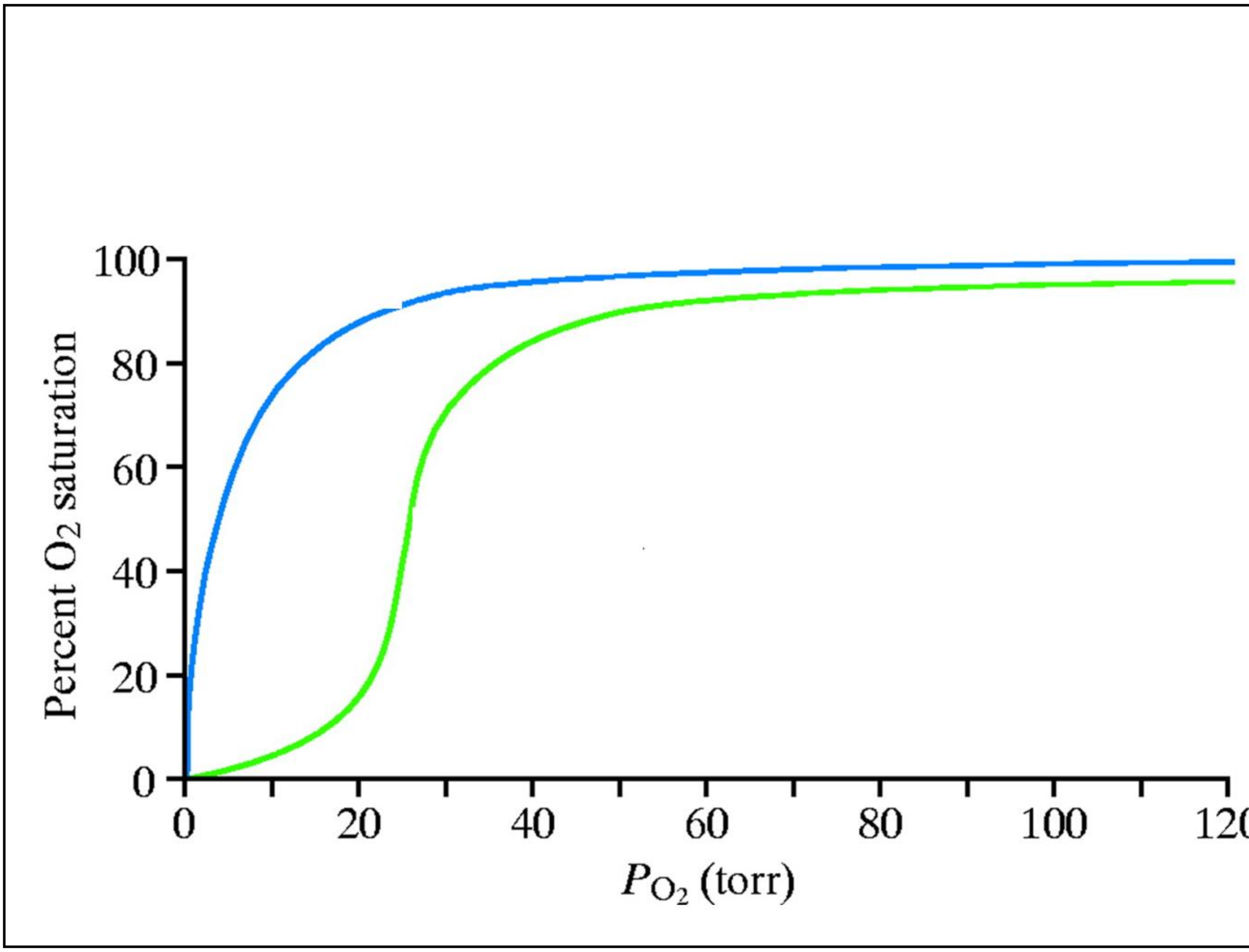


Myoglobin (Mb)

Binds 1 oxygen aggressively

Binds oxygen for use in **muscles**





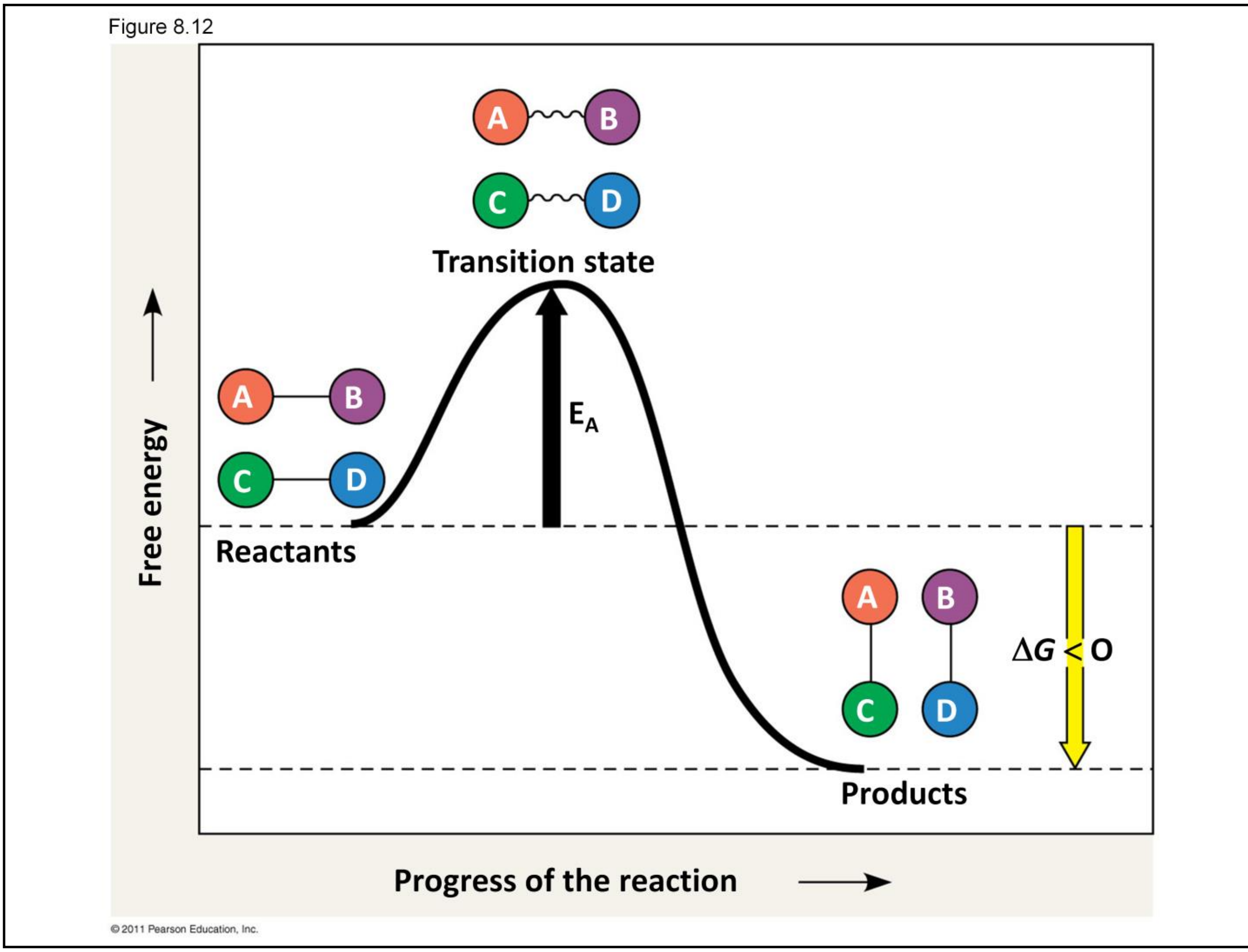
Which line represents **Hb** and which represents **Mb**?
Justify your response with data from the previous slide.

1. Which of the following is a consequence of the different intramolecular interactions among biomolecules?
    a. Carbohydrates are better suited as long-term energy storage molecules than lipids.
    b. Lipids are better suited as long-term energy storage molecules than carbohydrates.
    c. Nucleic Acids are better suited as catalysts than proteins.
    d. Proteins are better suited as information coding molecules than nucleic acids.

2. Which of the following describes an important intermolecular interaction among biomolecules?
    a. The secondary structure of a protein.
    b. The tertiary structure of a protein.
    c. The primary structure of a protein.
    d. The quaternary structure of a protein.

3. Which of the following processes would be least disrupted by errors in intermolecular interactions?
    a. Transcription
    b. Formation of protein secondary structure
    c. DNA replication
    d. Formation of protein primary structure

Enzymes



Every chemical reaction between molecules involves bond breaking and bond forming.

The initial energy needed to start a chemical reaction is called the free energy of activation, or **activation energy (E_A)**.

Activation energy is often supplied in the form of thermal energy that the reactant molecules absorb from their surroundings.

Enzymes

Speed up metabolic reactions by lowering energy barriers

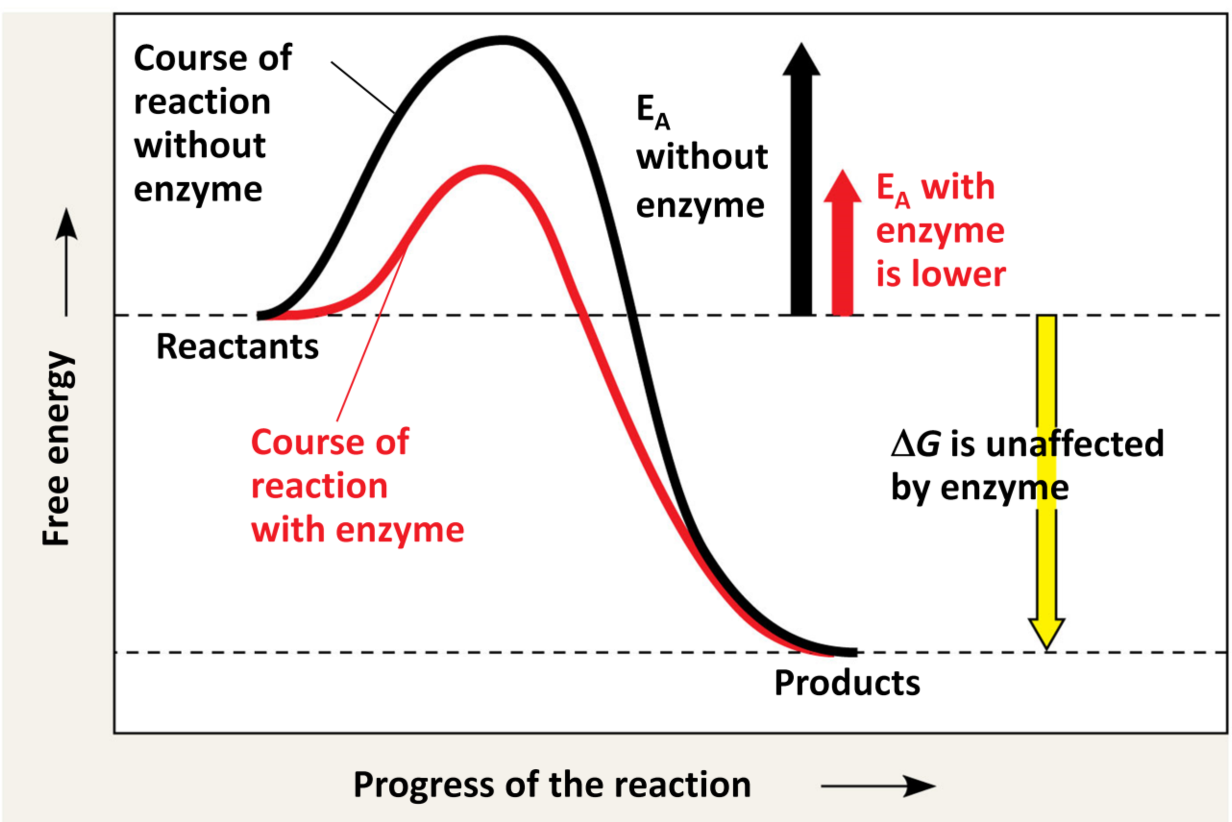
A **catalyst** is a chemical agent that speeds up a reaction without being consumed by the reaction

An **enzyme** is a catalytic protein

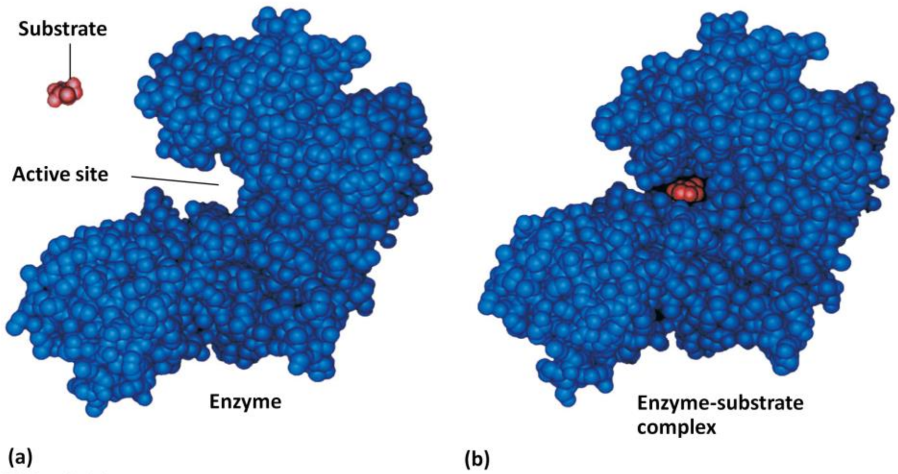
Enzymes catalyze reactions by lowering the E_A barrier

Enzymes do not affect the change in free energy (ΔG); instead, they hasten reactions that would occur eventually

Figure 8.13



Substrate Specificity of Enzymes

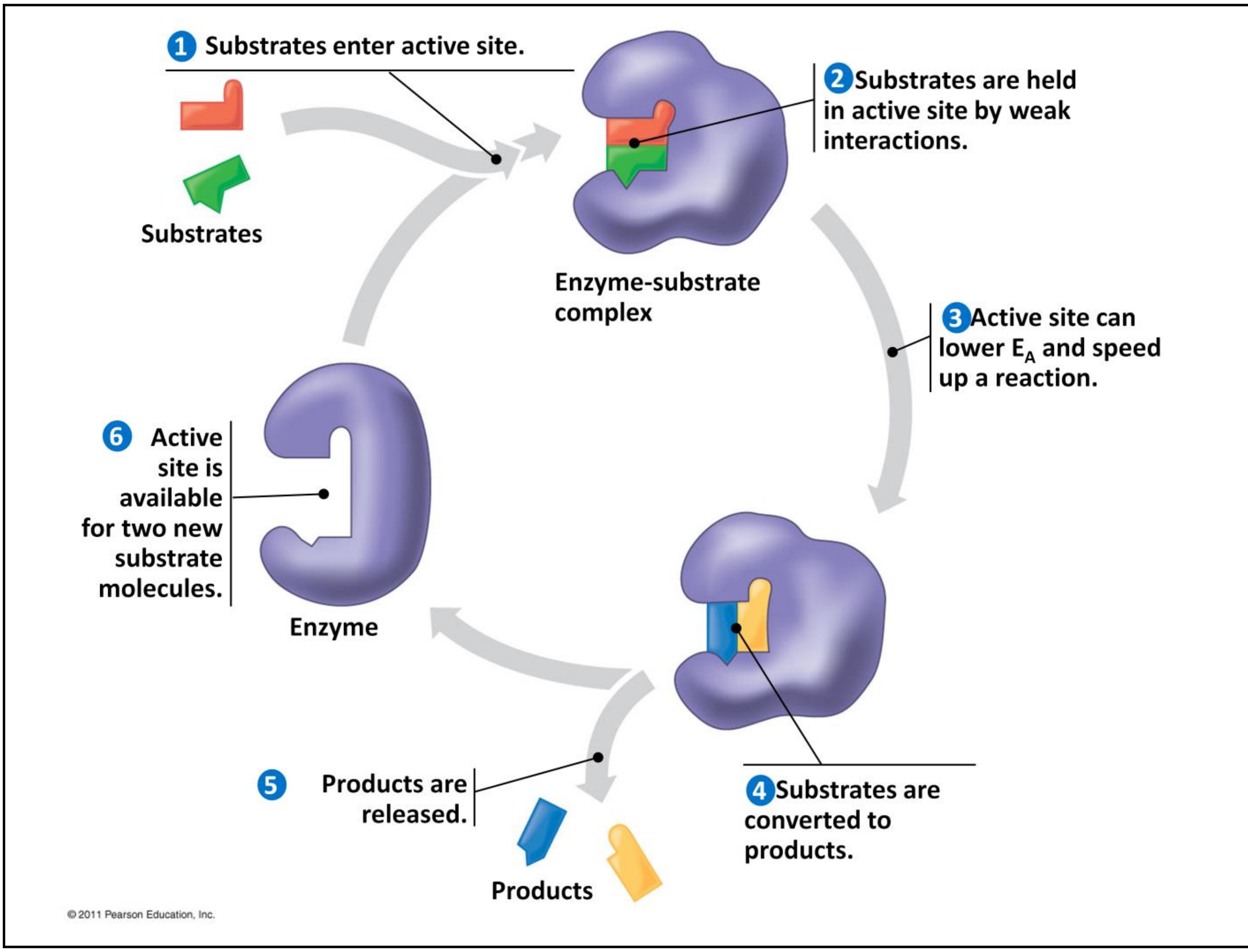


The reactant that an enzyme acts on is called the enzyme's **substrate.**

The enzyme binds to its substrate, forming an **enzyme-substrate complex.**

The **active site** is the region on the enzyme where the substrate binds.

Induced fit of a substrate brings chemical groups of the active site into positions that enhance their ability to catalyze the reaction.



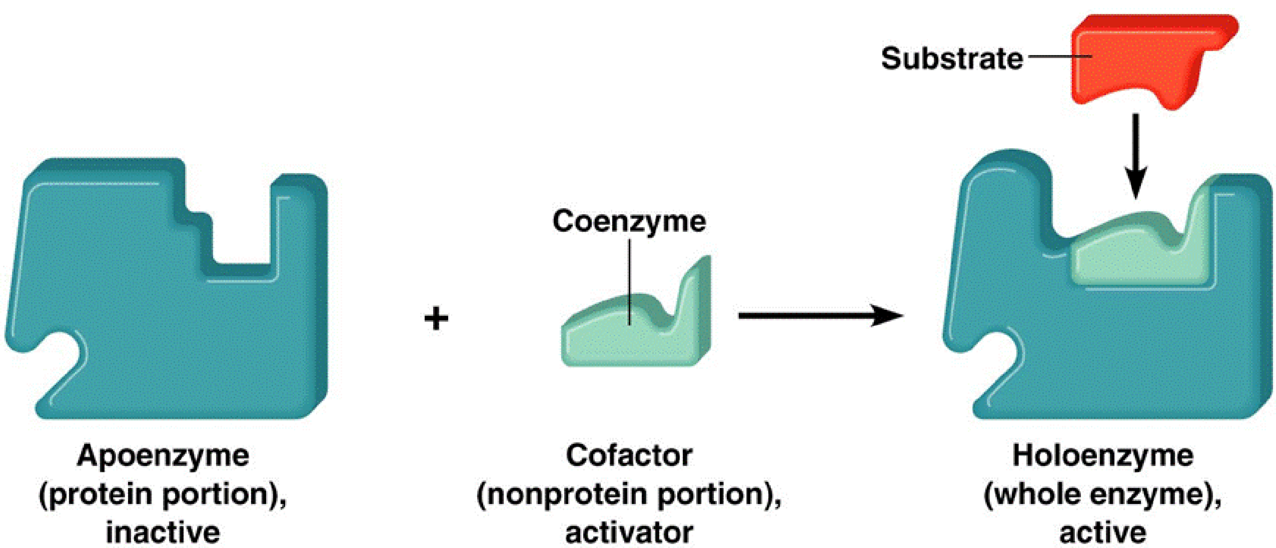
In an enzymatic reaction, the substrate binds to the active site of the enzyme

The active site can **lower an E_A** barrier by

- Orienting substrates correctly
- Straining substrate bonds
- Providing a favorable microenvironment
- Covalently bonding to the substrate

Cofactors

- **Cofactors** are nonprotein enzyme facilitators
- Cofactors may be inorganic (such as a metal in ionic form) or organic
- An organic cofactor is called a **coenzyme**
- Coenzymes include vitamins



1. Consider a biochemical reaction A $\rightarrow$ B, which is catalyzed by the enzyme AB dehydrogenase. Which of the following statements is most accurate?
    a. The reaction will proceed until the enzyme concentration decreases.
    b. The reaction will be more favorable at body temperature.
    c. A component of the enzyme is transferred from A to B
    d. The free energy change, ΔG of the catalyzed reaction is the same as the free energy of the uncatalyzed reaction.

2. A particular enzyme-catalyzed reaction was studied in the presence of iron & vitamin B12. With iron, the reaction proceeded at half the speed as compared to the speed in the presence of vitamin B12. The reaction does not occur in the absence of iron or vitamin B12. Which of the following best describes the interactions in this example?
    a. Iron decreases ΔG whereas B12 does not.
    b. B12 decreases ΔG whereas iron does not.
    c. Iron & B12 are both coenzymes that assist in the reaction.
    d. Iron & B12 are both cofactors that assist in the reaction.

3. For the same reaction described in #2, which question would best address the reasoning for different rates of the reaction in the presence of B12 & iron?
    a. Do B12 & iron have the same effect on reaction speed?
    b. Is this enzyme used for 1 substrate exclusively?
    c. Does temperature play a role in the enzyme kinetics?
    d. Is iron a now obsolete version of a cofactor that has been replaced by B12?

Effects of Local Conditions on Enzyme Activity

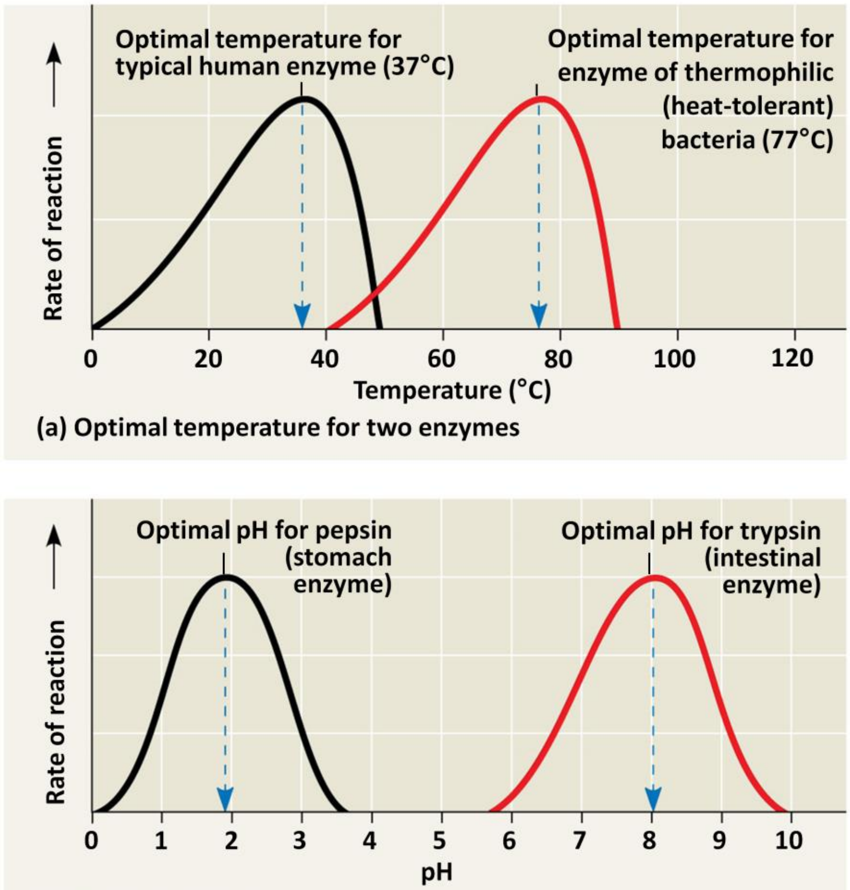
- An enzyme's activity can be affected by
  - General environmental factors, such as temperature and pH
  - Chemicals that specifically influence the enzyme

Each enzyme has an optimal temperature in which it can function

Each enzyme has an optimal pH in which it can function

Optimal conditions favor the most active shape for the enzyme molecule

Figure 8.16

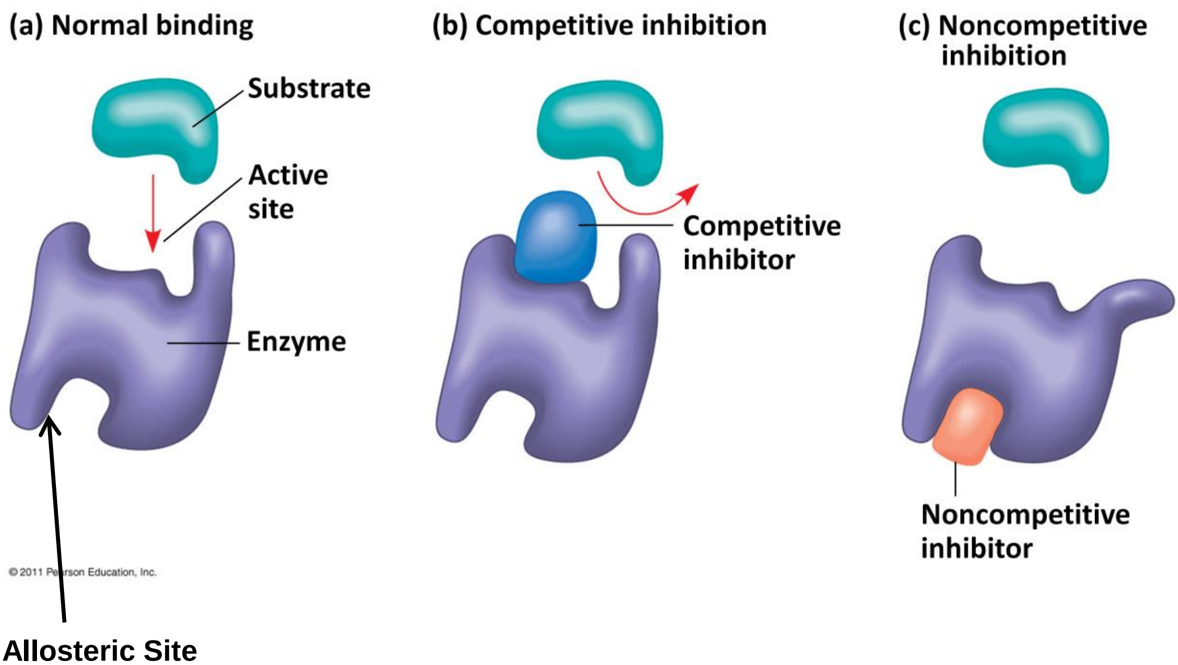


(a) Optimal temperature for two enzymes

(b) Optimal pH for two enzymes

For each graph, provide an example of a specific enzyme or organism body system that would have this enzyme. Justify your responses.

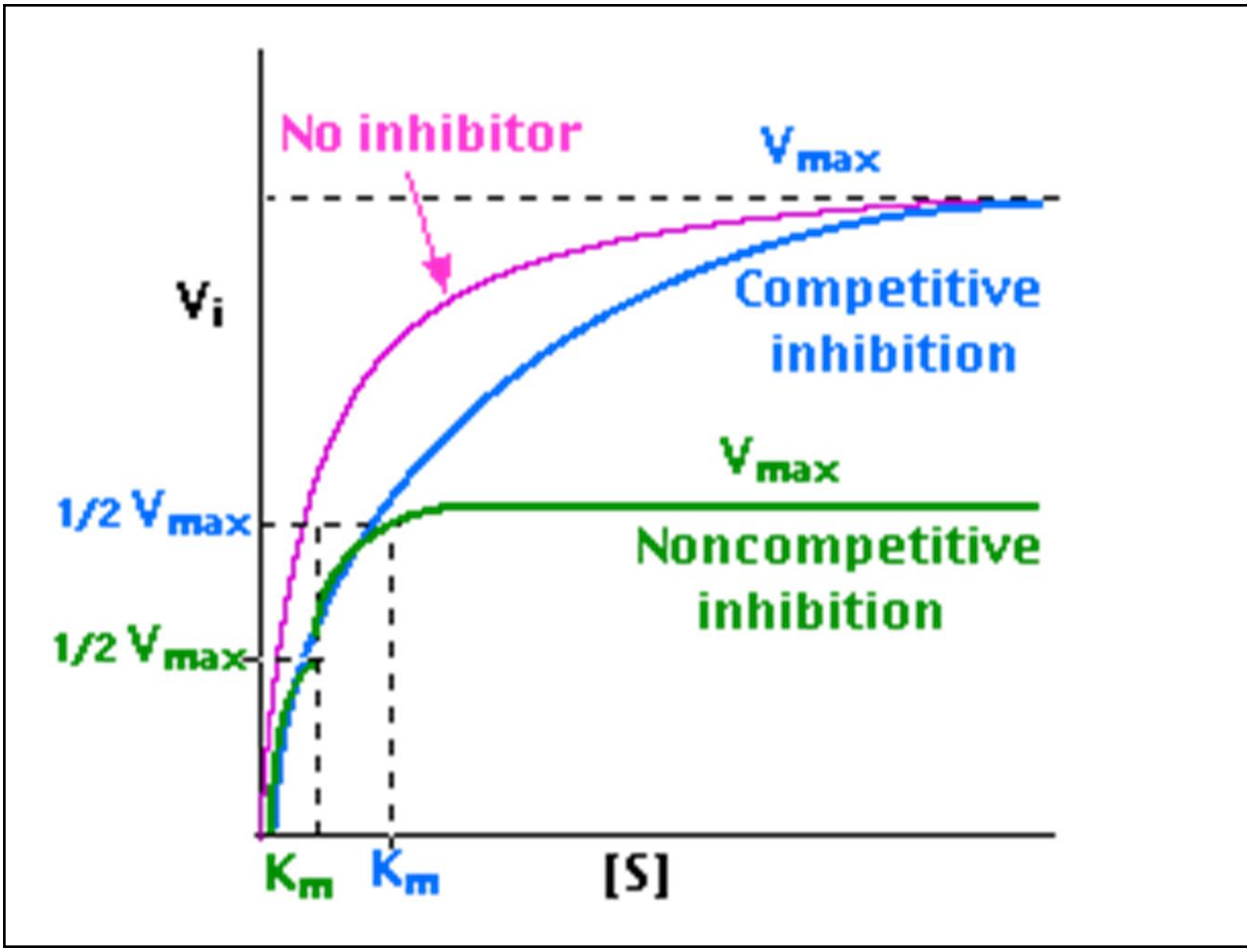
Enzyme Inhibitors



Competitive inhibitors bind to the *active site* of an enzyme, competing with the substrate.

Noncompetitive inhibitors bind to another part of an enzyme (*allosteric site*), causing the enzyme to change shape and making the active site less effective or completely ineffective.

Examples of inhibitors include toxins, poisons, pesticides, and antibiotics

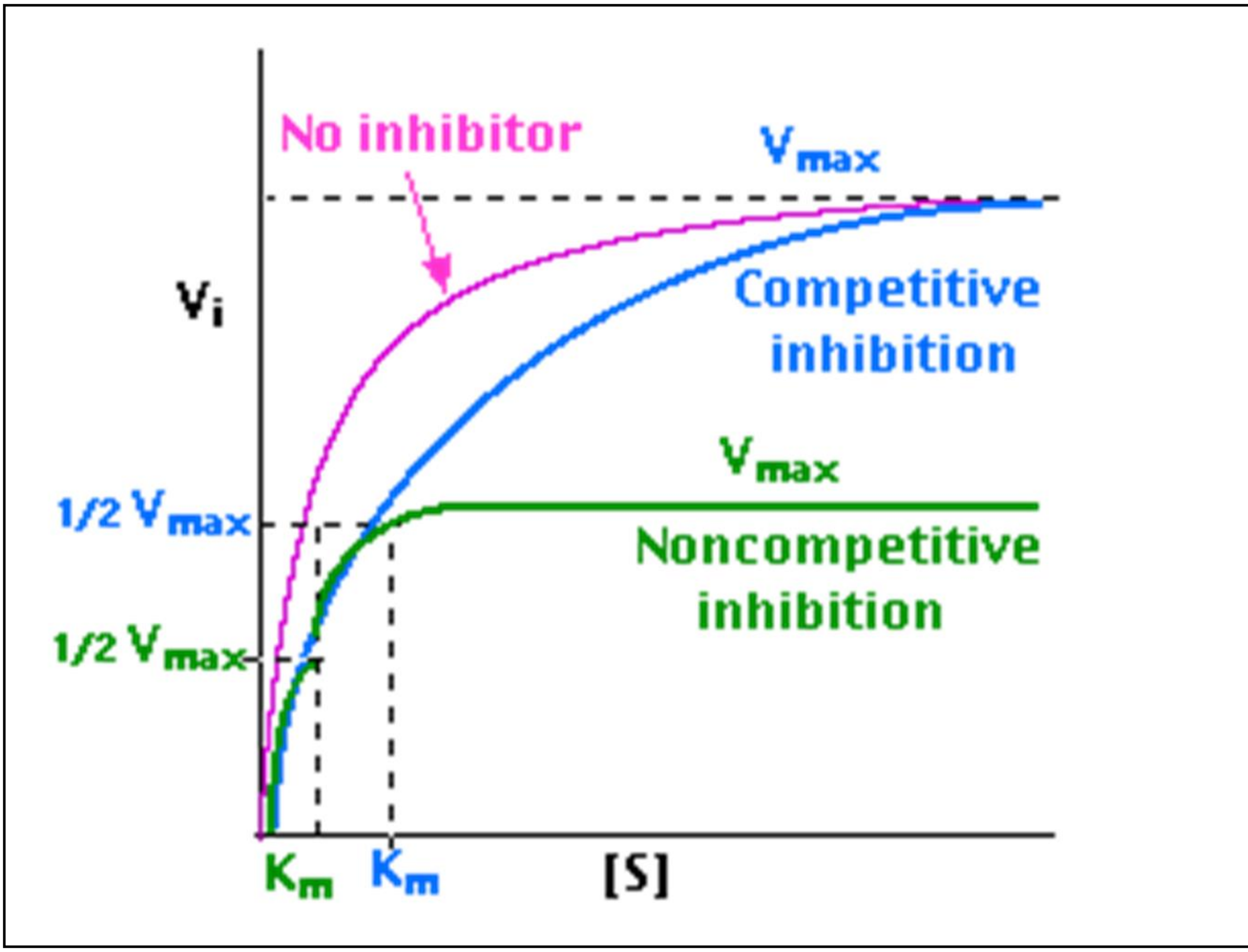


Vmax = maximum velocity of the enzyme; used to determine *maximum* rate of the enzyme as a function of increasing substrate concentration.

1/2 Vmax = Half the value of Vmax; used as a more accurate measure of enzyme's *steadiest* *rate* as a function of increasing substrate concentration.

Km = The **substrate concentration** at the **1/2 Vmax value** (Used to determine how *efficiently* the enzyme is converting substrate to product.

[S] = Concentration of the substrate; used to determine how the enzyme functions from low to high levels of substrate.



Using all the information on p.19-20, explain the trends in the graphs in terms of enzyme efficiency in the presence of a competitive vs. a non-competitive inhibitor.

Which type of inhibitor would be the most harmful? Explain.

Regulation of enzyme activity helps control metabolism

- Chemical chaos would result if a cell's metabolic pathways were not tightly regulated
- A cell does this by switching on or off the genes that encode specific enzymes or by regulating the activity of enzymes

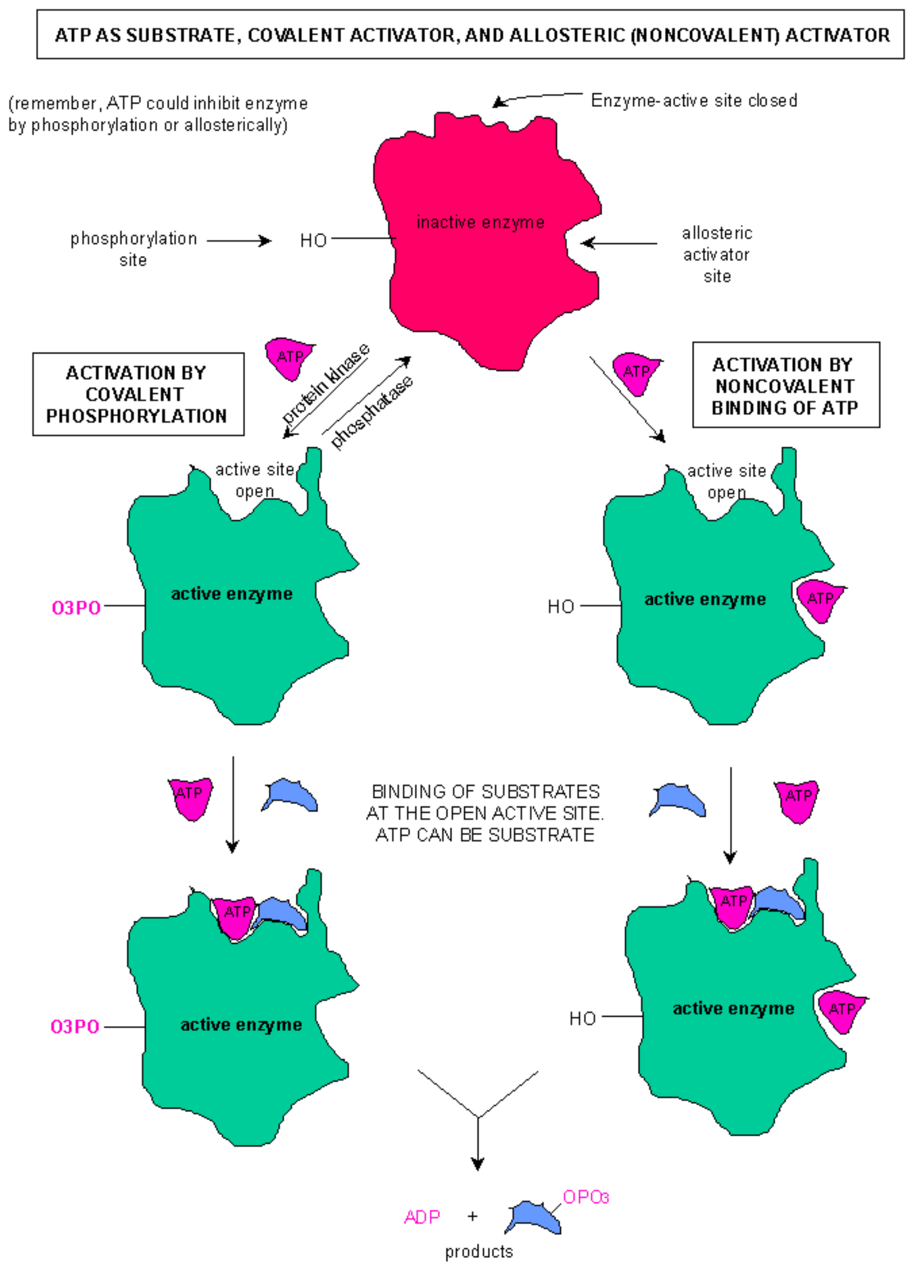
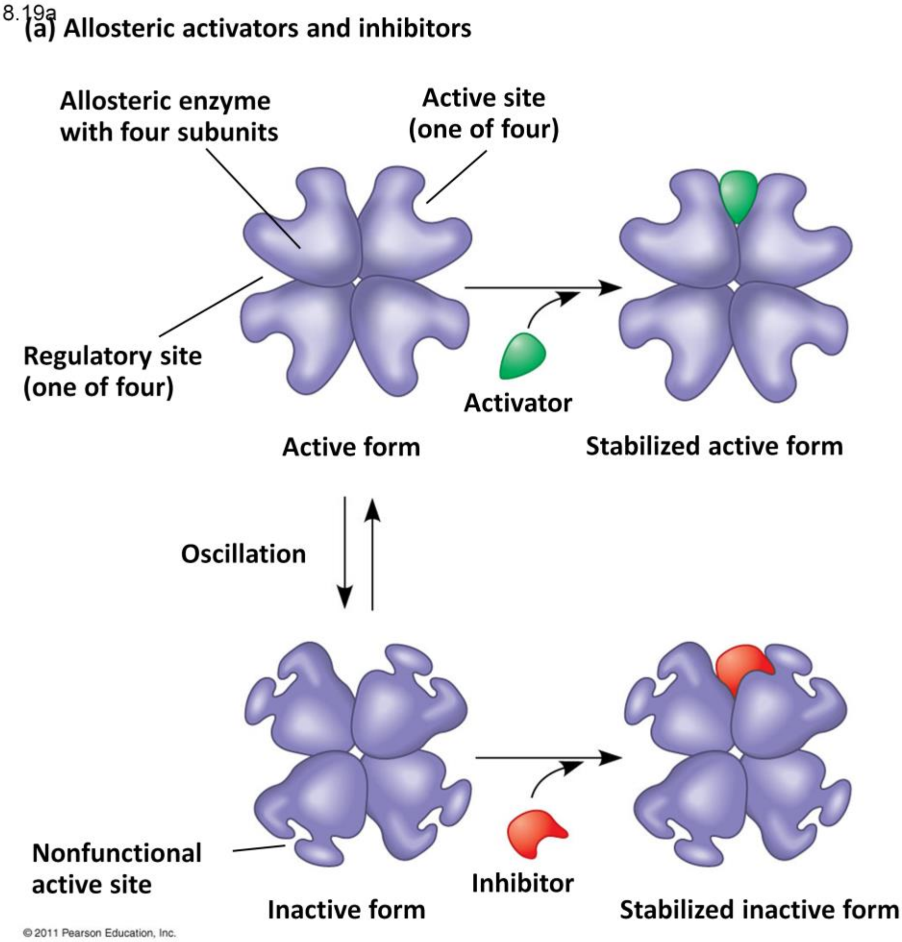


Figure 8.19a



Allosteric Regulation of Enzymes

Allosteric regulation may either inhibit or stimulate an enzyme's activity

Allosteric regulation occurs when a regulatory molecule binds to a protein at one site and affects the protein's function at another site

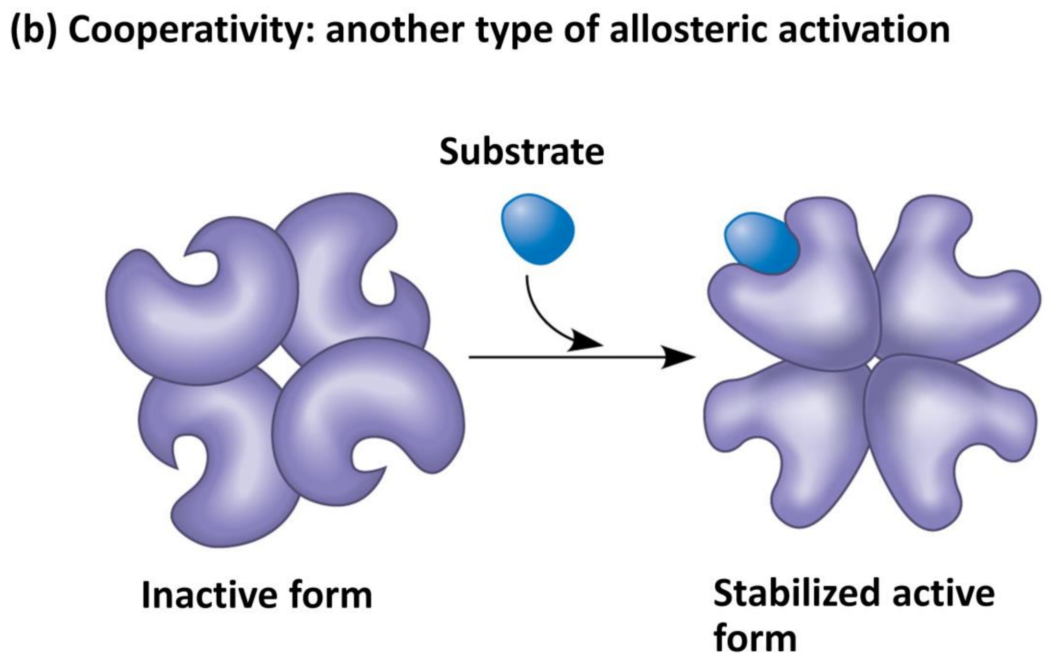
Most allosterically regulated enzymes are made from polypeptide subunits (Quaternary Structure)

Each enzyme has active and inactive forms

The binding of an **activator** stabilizes the active form of the enzyme

The binding of an **inhibitor** stabilizes the inactive form of the enzyme

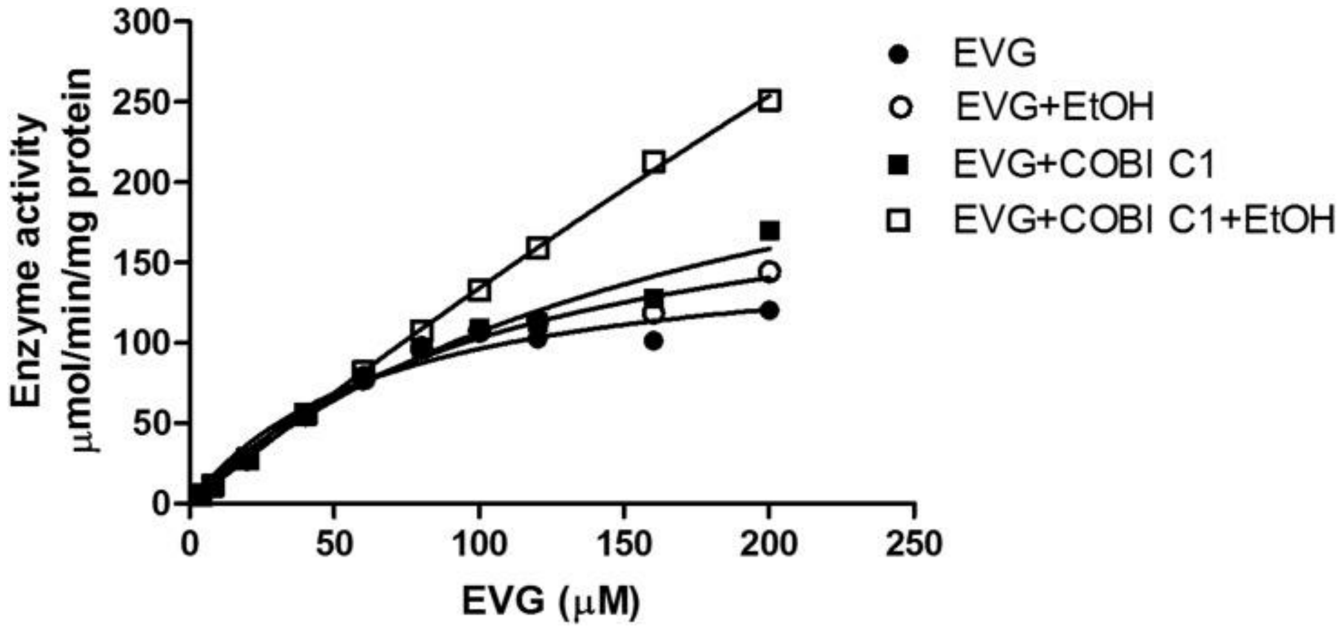
Figure 8.19b



Cooperativity is a form of allosteric regulation that can amplify enzyme activity

One substrate molecule primes an enzyme to act on additional substrate molecules more readily

Cooperativity is allosteric because binding by a substrate to one active site affects catalysis in a different active site



An enzyme responsible for allowing HIV to dock & insert its genetic material can be inhibited by a drug called elvitegravir (EVG). The figure above shows the enzyme activity as EVG concentrations are increased, along with its effectiveness in the presence of other drugs (Ethyl Alcohol – EtOH; Cobicistat - COBI C1)

1. Which of the following is most consistent about a patient taking EVG according to the data provided?
    a. A patient who consumes alcohol would likely have more reduced symptoms than a patient who does not consume alcohol.
    b. A patient who consumes alcohol & is taking Cobicistat would likely have more reduced symptoms than a patient who only consumes alcohol.
    c. A patient who consumes alcohol would likely have worse symptoms than a patient who does not consume alcohol.
    d. A patient who only consumes alcohol would likely have worse symptoms than a patient that is taking Cobicistat

2. According to the data, which of the following best describes the interactions of EVG & the enzyme?
    a. EVG is most likely a non-competitive inhibitor
    b. EVG is most likely a competitive inhibitor
    c. EVG is most likely a cofactor
    d. EVG is most likely an allosteric activator

3. Which of the following questions would best answer the question of whether the enzyme is a single polypeptide unit or a cooperative group of polypeptides?
    a. Do the kinetics display a drop in activity after an initial substrate is bound?
    b. Do the kinetics remain linear over the course of changing substrate concentration?
    c. Do the kinetics begin slow and then increase as substrate is increased?
    d. Do the kinetics follow a steady increase as substrate is increased?

Intracellular Interactions

- Interactions among cell parts contribute to a cell's specialty
  - Nerve cells
    - Numerous Ion channels in membrane
    - Mitochondria for ATP
    - Vesicles with neurotransmitters
  - White Blood Cells
    - Lysosomes for pathogen digestion
    - Golgi to produce lysosomes
    - Specialized membrane receptors

1. Ribosomes

a. Small, universal structures

b. 2 interacting parts: rRNA & Protein

c. Interact to become sites of protein synthesis

d. Translation of genetic information yields specific polypeptides.

1. Ribosomes

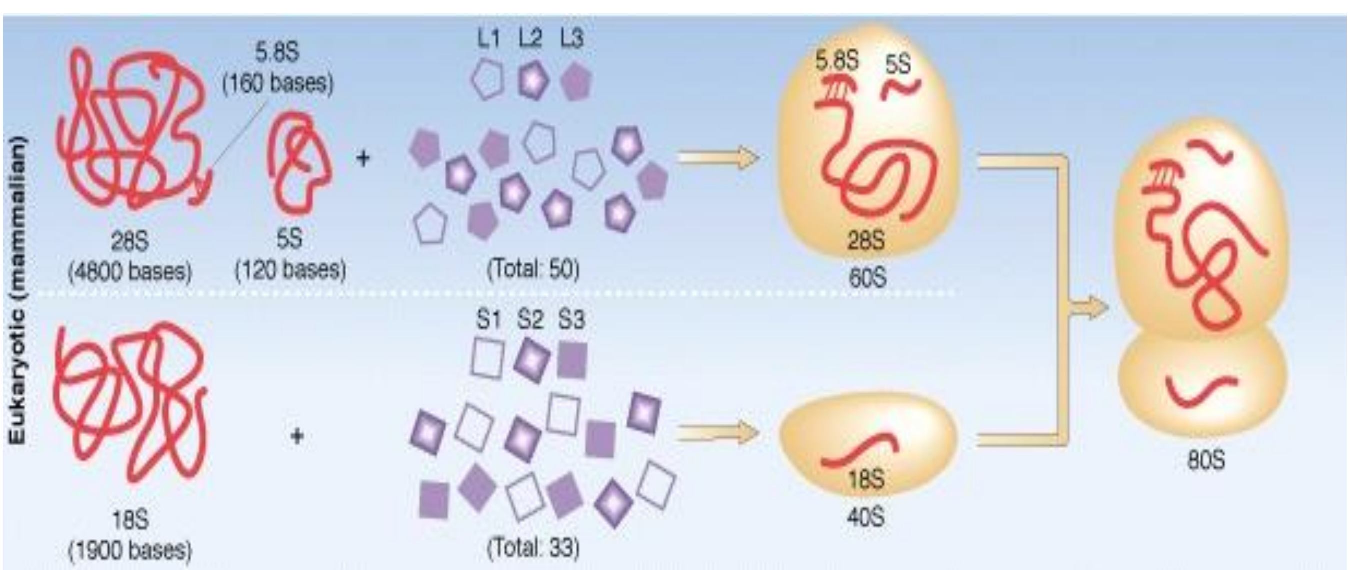
e. Can be "free" or "attached"

f. **Free** ribosomes are in the cytosol and produce proteins that will **remain** in the cytosol.

- Glycolysis enzymes – Actin of cytoskeleton

g. **Attached** ribosomes are embedded in the Rough ER membranes. These protein products will be **secreted** out of the cell OR become **embedded** in the plasma membrane.

- Sebum of sweat glands
- Membrane receptor proteins



2. Endoplasmic Reticulum

a. 2 forms, Rough & Smooth

b. Rough ER:

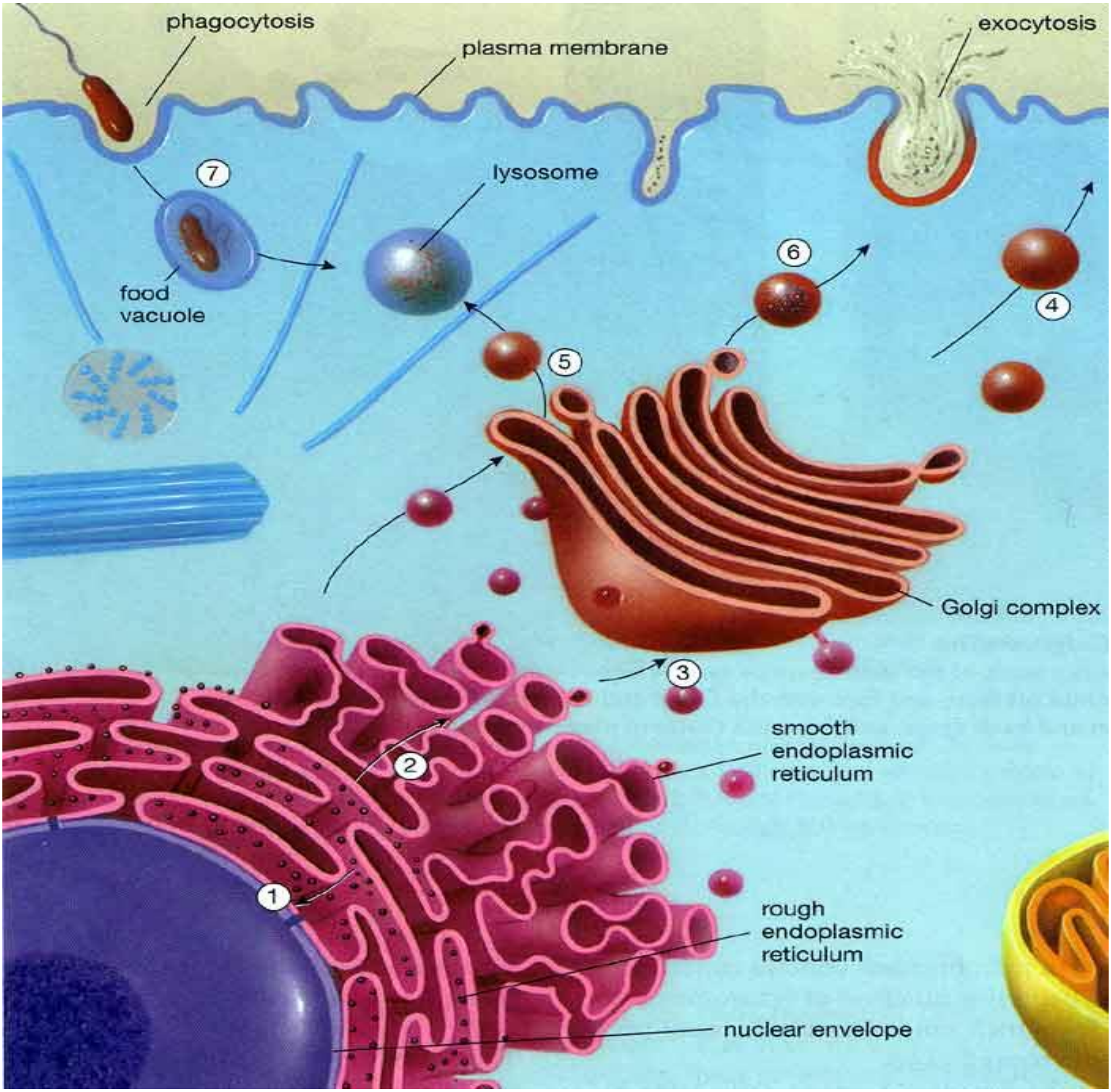
1. Compartmentalizes cell
2. Provides mechanical support
3. Intracellular Transport
4. Protein synthesis

c. Smooth ER:

1. Synthesizes Lipids

3. Golgi Complex

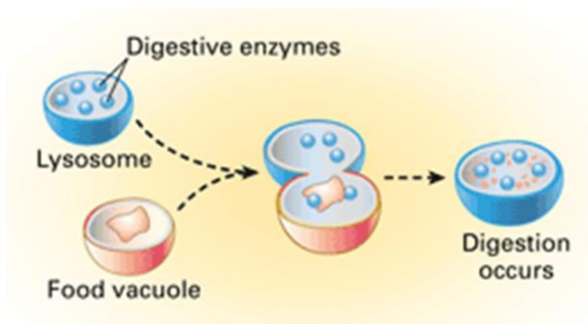
a. Series of flattened membrane sacs (cisternae)
b. Synthesize & Package small molecules for transport in vesicles.
c. Produce Lysosomes.


phagocytosis
plasma membrane
exocytosis
7
lysosome
food
vacuole
6
4
5
Golgi complex
3
smooth
endoplasmic
reticulum
2
1
rough
endoplasmic
reticulum
nuclear envelope

4. Lysosomes

a. Membranous sacs containing hydrolytic enzymes important for:

1. Intracellular digestion
2. Apoptosis
3. Recycling of organic materials



5. Vacuoles

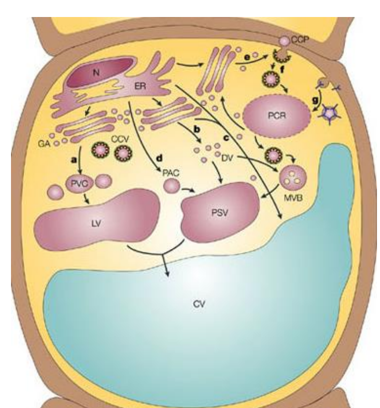
a. Membranous sacs

b. Intracellular digestion

c. Release waste products.

d. Plant vacuoles: Variety of functions

1. Pigment storage
2. Cell growth
3. Containing toxins
4. Large SA/V ratio

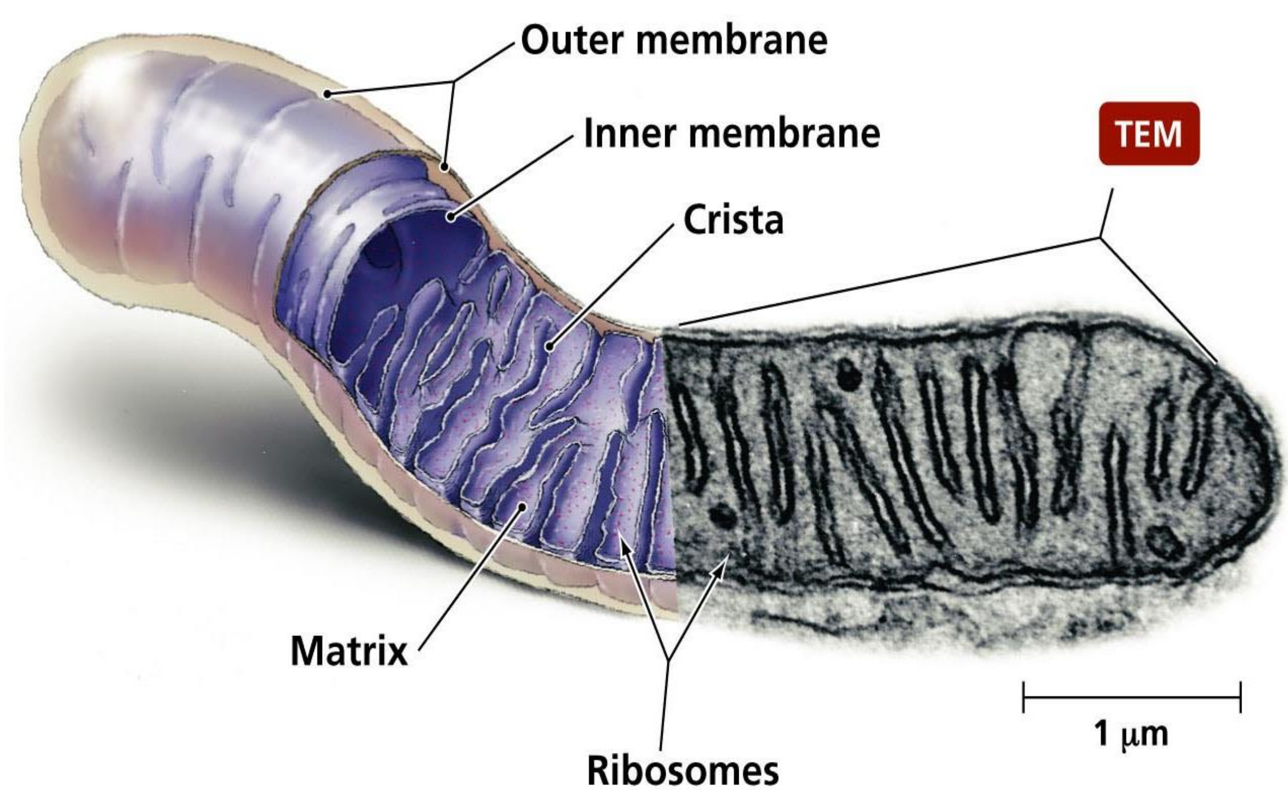


6. Mitochondria

a. Energy capture & transformation

b. Double-membrane allowing for compartmentalization that is inherent to its function.

c. Smooth outer membrane, folded inner membrane (cristae) containing enzymes for ATP production. Folds increase surface area!



7. Chloroplasts

a. Algae & Plants

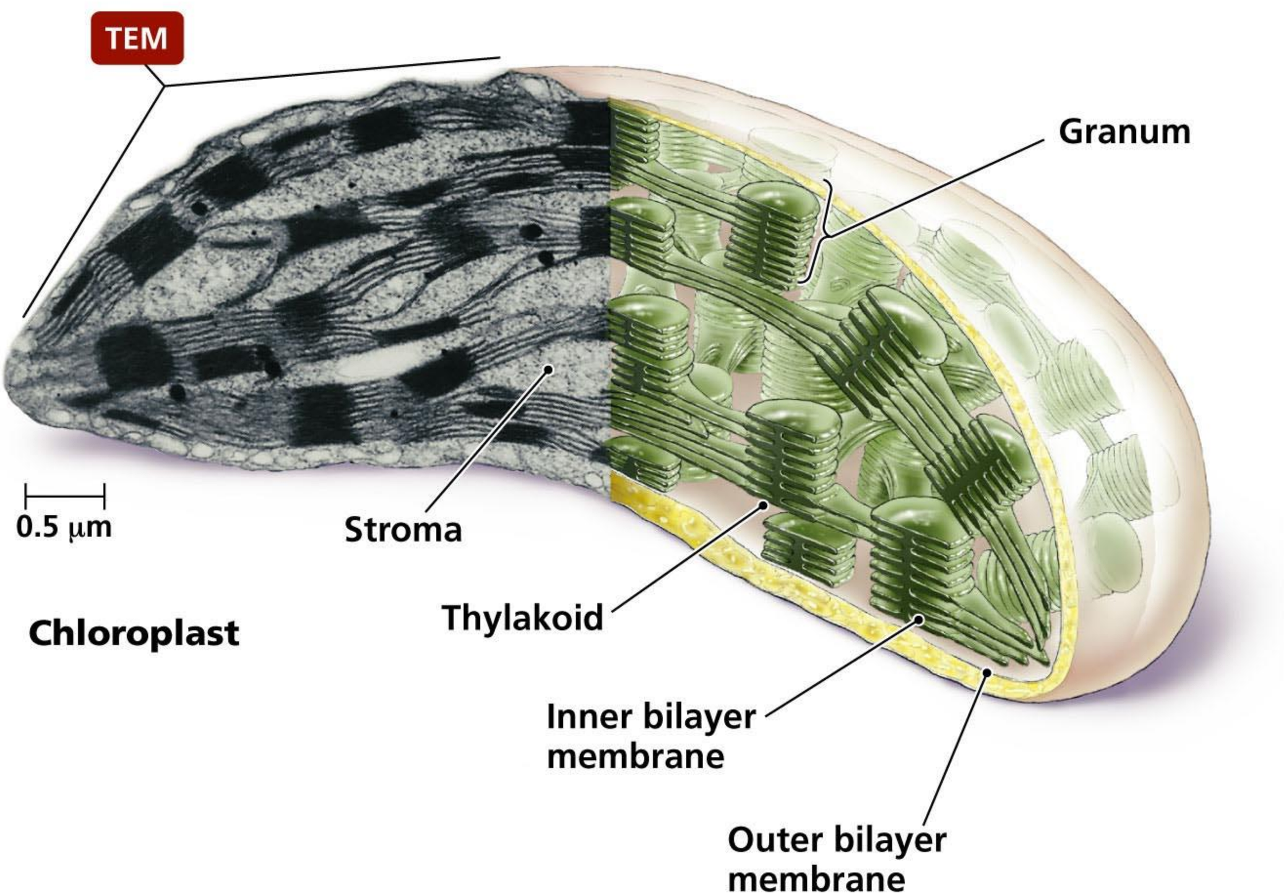
b. Photosynthesis

c. Capture energy in sunlight and convert into chemical bond energy (sugars).

d. A variety of Chlorophylls, but "*a*" primarily

e. Double-membrane compartmentalizes functions.

f. Thylakoids in groups called grana that produce ATP & NADPH, used to power the Calvin Cycle in the stroma, where CO_2 is converted into sugars.



The following data were collected by observing subcellular structures of three different types of eukaryotic cells.

RELATIVE AMOUNTS OF ORGANELLES IN THREE CELL TYPES

Cell Type	Smooth ER	Rough ER	Mitochondria	Cilia	Golgi Bodies
X	Small amount	Small amount	Large number	Present	Small amount
Y	Large amount	Large amount	Moderate number	Absent	Large amount
Z	Absent	Absent	Absent	Absent	Absent

1. Which description best characterizes the function of cell X?
    a. A cell used to sweep egg cells through fallopian tubes
    b. A cell used for muscle contraction
    c. A cell used for nerve transmission
    d. A cell used to transport oxygen

2. Which function least characterizes cell Y?
    a. Producing hormones
    b. Producing neurotransmitters
    c. Producing transport channels
    d. Producing contractions

3. Which question would best address the function of cell Z?
    a. Were there errors in the organelle observations?
    b. Does the cell have DNA?
    c. Does the cell have ribosomes?
    d. Does the cell respond to cell signals?

Intercellular Interactions

- Interactions among cells contribute to specialized functions
  - Nerve cells & Muscle cells
  - Phloem cells & Parenchyma cells

Organ/System Interactions

Interactions & coordination between organs provide essential biological activities.

Roots, stems, leaves

Stomach, small intestine, pancreas

Interactions between organ systems provide essential biological activities.

Respiratory & Circulatory

Nervous & Muscular

Population Interactions

- In order to understand interactions within ecosystems, each population must be understood
  - Size
  - Density
  - Dispersion Patterns
  - Limiting Factors
  - Life Histories (reproductive cycle)

Population Dynamics

Population: all the individuals of a species that live together in an area

Demography: the statistical study of populations, make predictions about how a population will change

Key Features of Populations

1. Size: number of individuals in an area

Population Growth Rate in a time interval: Birth Rate (natality) - Death Rate (mortality)

How many individuals are born vs. how many die

Population Growth Rate (*r*) = Birth rate (*b*) − death rate (*d*)

$$r = b - d$$

Also shown as

$$dN/dt = B-D$$

If no other information is given, this is how we determine a change in a population.

Other factors such as emigration & immigration also affect the size & density.

Key Features of Populations

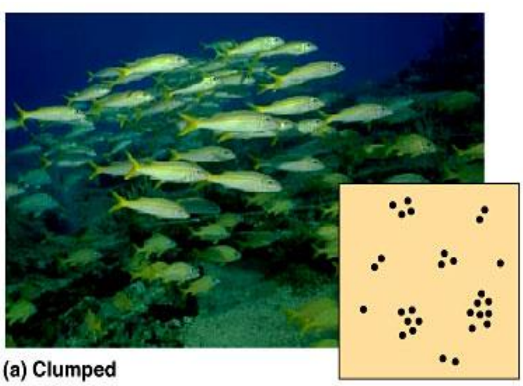
2. Density: measurement of population per unit area or unit volume

Formula: $D_p = \frac{N}{S}$

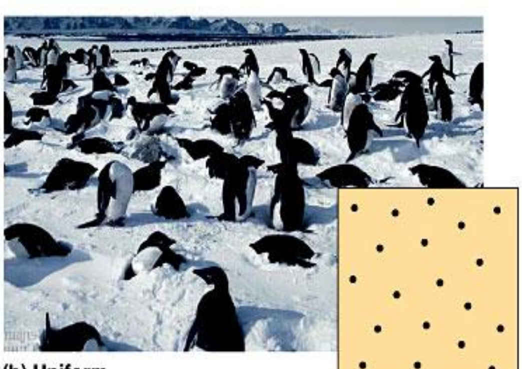
Pop. Density = # of individuals ÷ unit of space

Size measures the total population whereas density is more concerned with the average number of individuals that could be found per unit of space (acre, hectare, etc.)

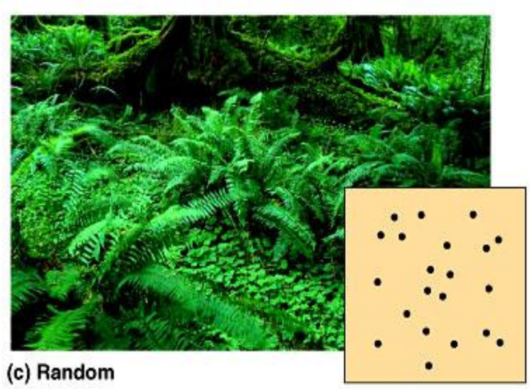
Population Dispersion



(a) Clumped



(b) Uniform



(c) Random

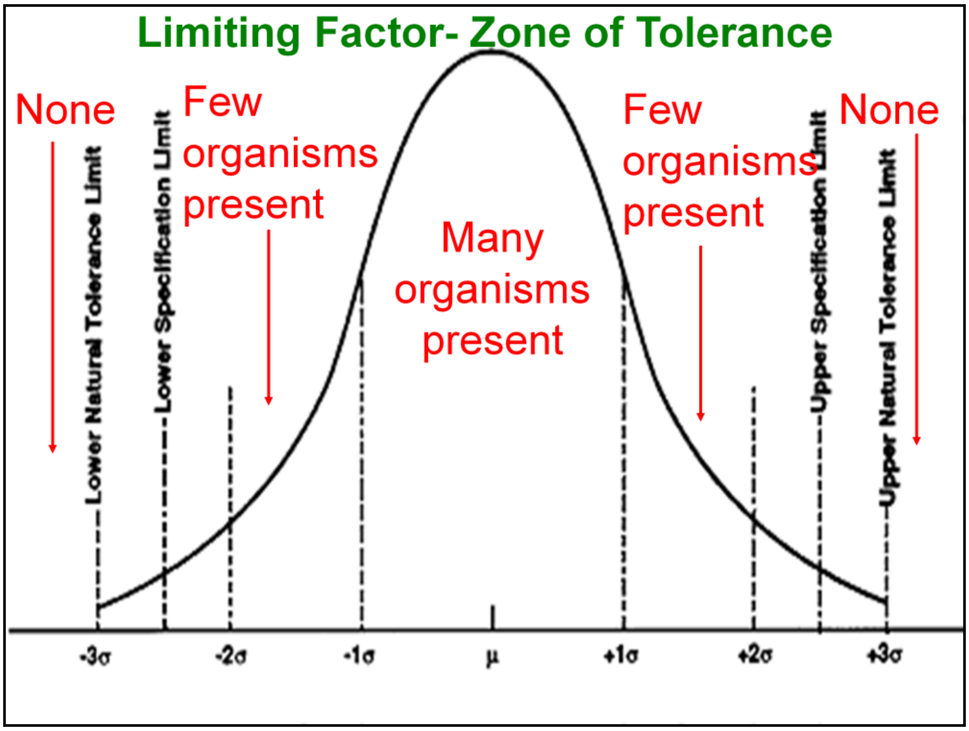
Other Factors that affect density

1. **Density-dependent factors-** Biotic factors in the environment that have an increasing effect as population size increases

Ex. disease
competition
parasites

2. **Density-independent factors-** Abiotic factors in the environment that affect populations regardless of their density

Ex. temperature
storms
habitat destruction
drought



Limiting factor- **any biotic or abiotic factor that restricts the existence of organisms in a specific environment.**

EX.- **Amount of water**

Amount of food

Temperature

Common rats native to Pennsylvania often carry more parasites than the Kangaroo rats native to the deserts of North America.

- Identify 1 limiting factor for the Kangaroo rat not faced by the common rat.
- Provide reasoning for why the common rat is more prone to parasites.
- Describe 1 density-independent factor the 2 rat species could have in common.

Growth Models

- Exponential Growth – Assumes no limits on resources, no competition, no predation
- **$\Delta N/\Delta t = r_{max}N$**

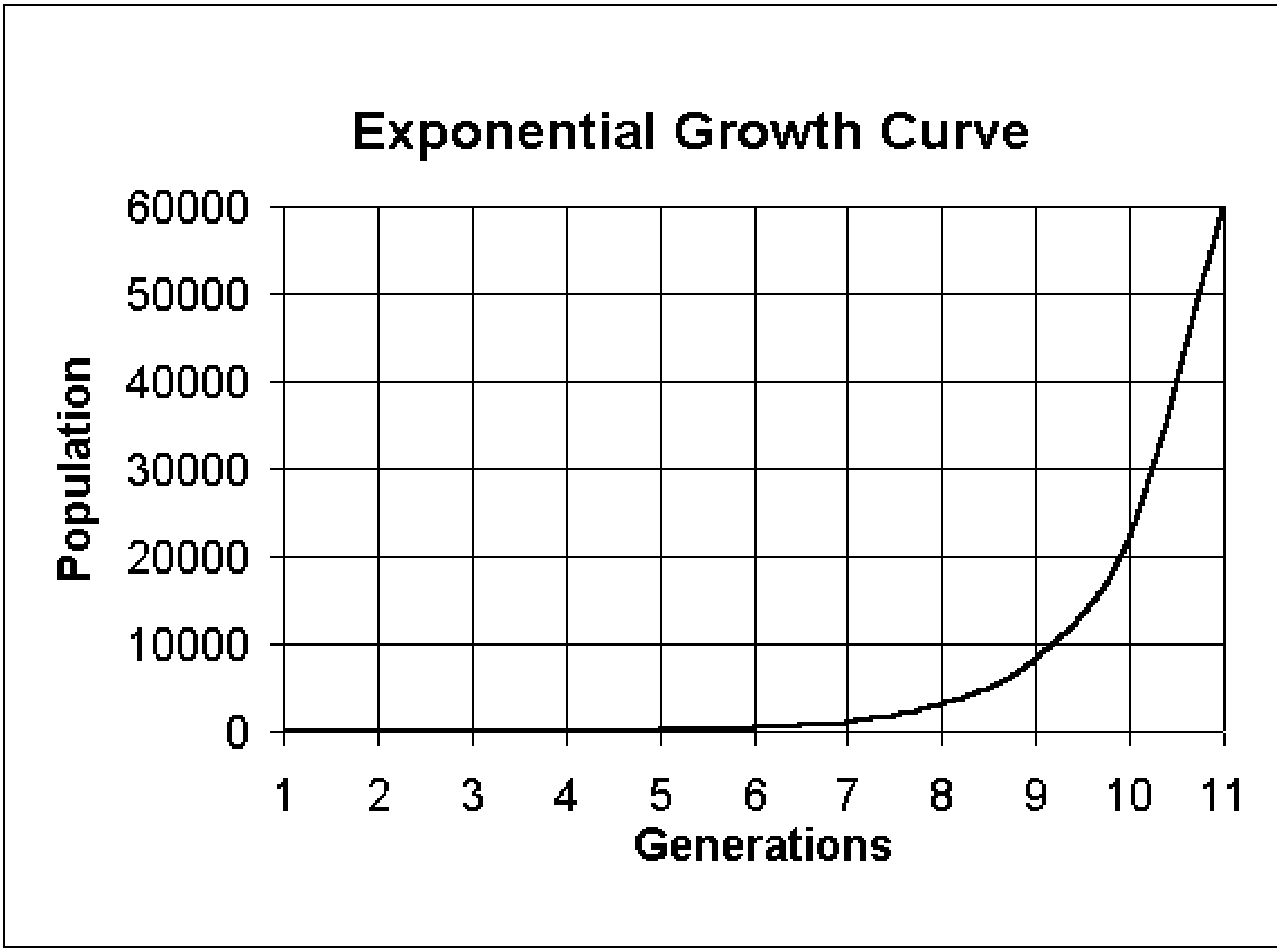
$r_{max} = 0.5$

year	0	1	2	3	4	5	6	7	8	9
N	50	75	113	169	253	380	570	855	1283	1924

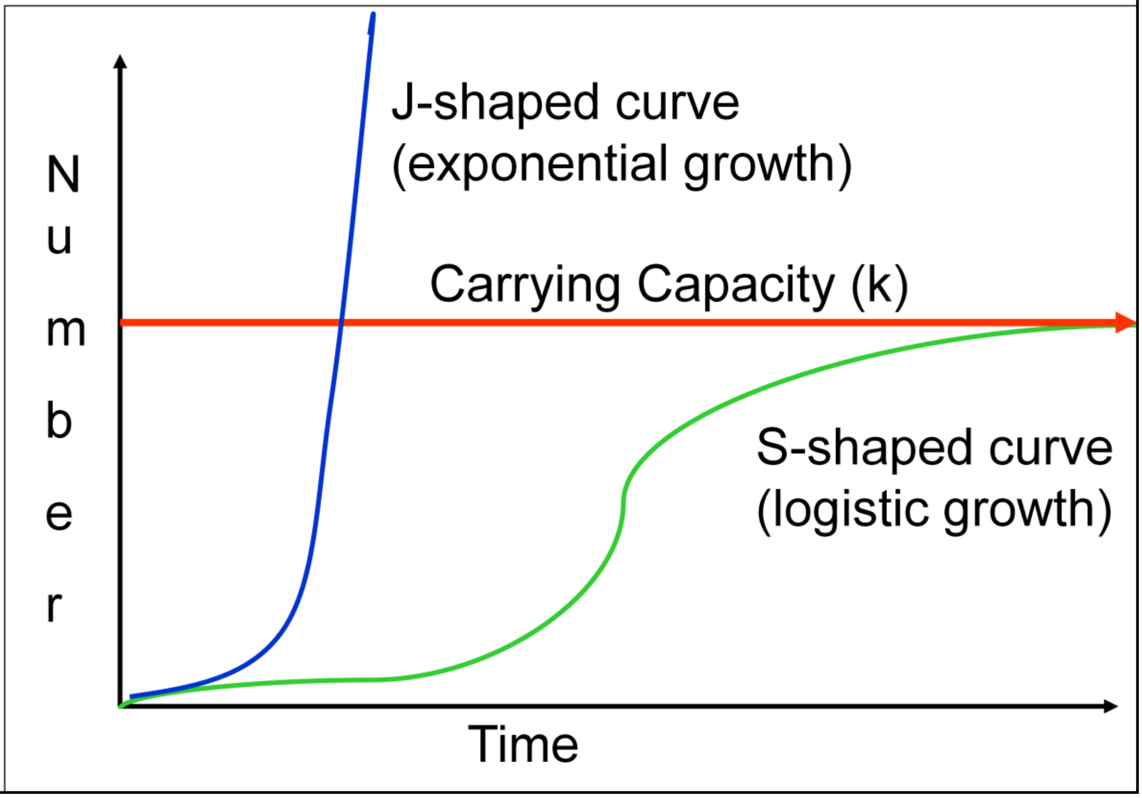
r_{max} is the per capita (average per individual) rate of growth and is calculated by dividing the # births minus the # deaths and any changes due to immigration/emigration by the population size.

N Is the population size

dN/dt is the overall population growth rate (as compared to the per-capita growth rate concerning an individual)


Exponential Growth Curve
60000
50000
40000
30000
20000
10000
0
Population
1
2
3
4
5
6
7
8
9
10
11
Generations

Logistic Growth vs. Exponential Growth



Carrying Capacity- (K) the maximum population size that can be supported by the available resources

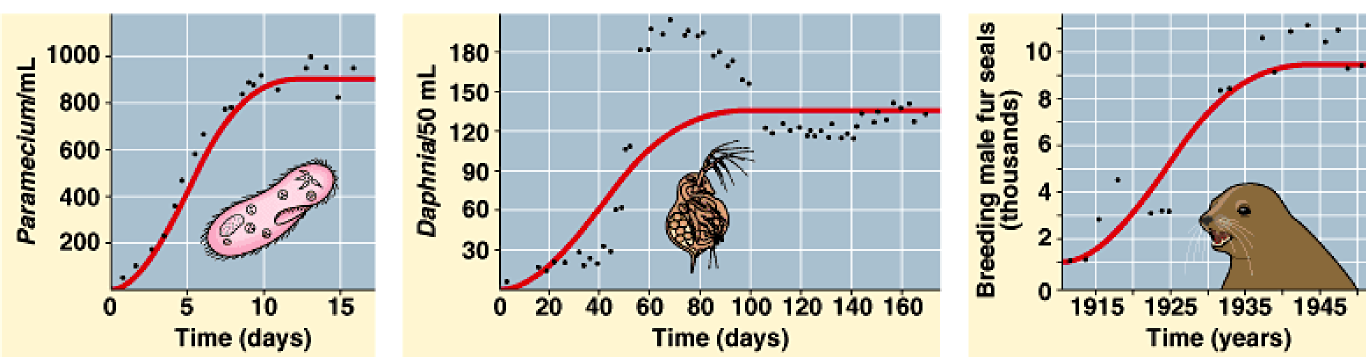
There can only be as many organisms as the environmental resources can support

Number varies on environment/species

Growth Models

- Logistic Growth: Factors in carrying capacity (K)
- K = 1000

Population Size: N	Intrinsic Rate of Increase: r_{max}	$\left(\frac{K-N}{K}\right)$	Per Capita Growth Rate: $r_{max}\left(\frac{K-N}{K}\right)$	Population Growth Rate:* $r_{max}N\left(\frac{K-N}{K}\right)$
20	0.05	0.98	0.049	+1
100	0.05	0.90	0.045	+5



(a) A *Paramecium* population in laboratory culture

(b) A *Daphnia* population in laboratory culture

(c) A fur seal (*Callorhinus ursinus*) population on St. Paul Island, Alaska

Life History Patterns

- 1. r-selection
  - short life span
  - small body size
  - reproduce quickly
  - have many young
  - little parental care
  - Ex: cockroaches, weeds, bacteria

Life History Patterns

- 2. K-selection
  - long life span
  - large body size
  - reproduce slowly
  - have few young
  - provides parental care
  - Ex: humans, elephants

Community Interactions

- How Organisms affect each other
- Analyzed by positive/negative outcomes

Predation

- Predator eats prey
- Win / Lose

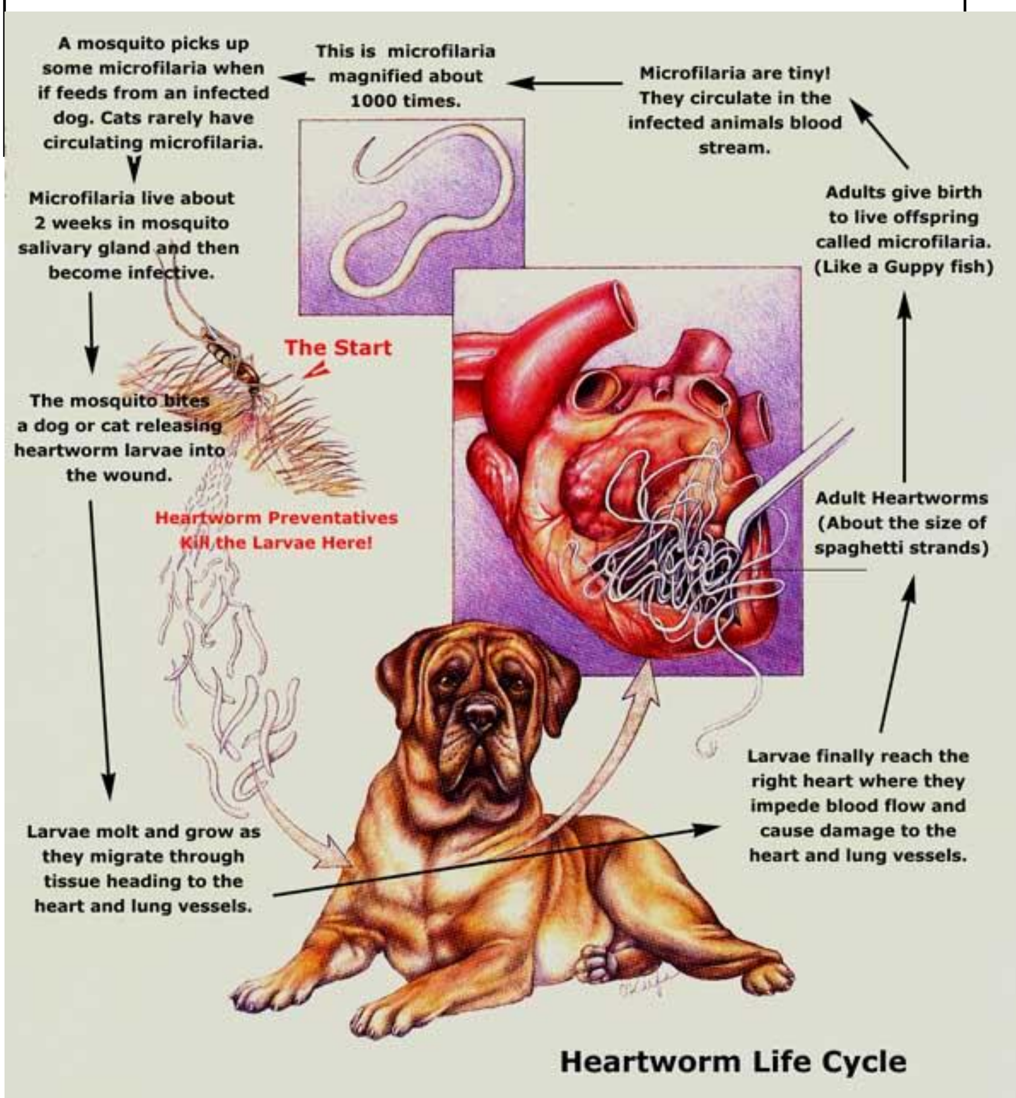
Herbivory

Animal eats a plant

Win/Lose

Parasitism

- Parasite lives inside host and harms the host.
  - Eats parts of the host
  - Reproduces inside of the host
- Win / Lose



Competition

- One organism fights another organism for food, land, water.
- Win / Lose OR Lose/Lose

Mutualism

2 organisms benefit from each other

Bee gets food **Plant transfers pollen**

Win / Win Usually

BUT possibly

Lose/Lose

Mimicry

- One organism looks like another

Batesian Mimicry

One **harmless** organism mimics appearance of a harmful organism

Mullerian Mimicry

2+ species have evolved (independently) similar appearances that both confer harm

Evaluate the 2 forms of mimicry by answering the following:

Which is beneficial to both species and why?

Which can be beneficial to one species and harmful to the other? Why?

Use authentic examples to justify your responses.

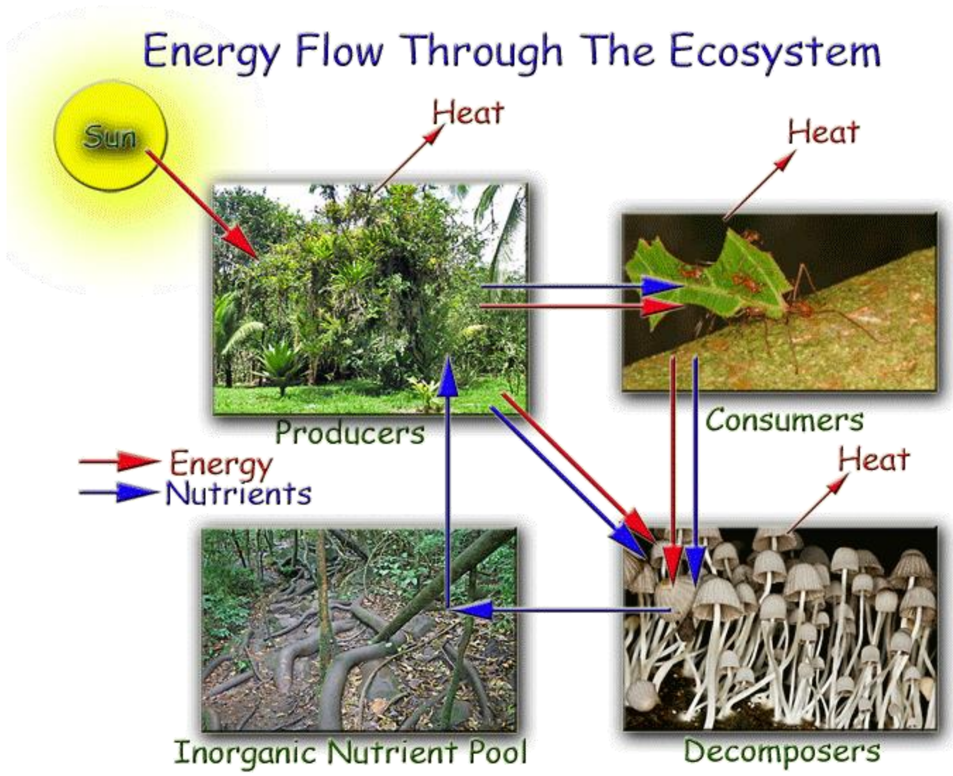
Species	Interaction of **vertical species** with **horizontal species**					**Life History**
	A	B	C	D	E	
A		+ +		- +		K-selection
B	+ +					r-selection
C				+ -	- +	K-selection
D	+ -		- +		- +	K-selection
E			+ -	+ -		r-selection

The table above shows the interactions between various species & their life history patterns. The species are as follows:

Lions, Acacia Trees, Ants, Ticks, & Giraffes

- Identify each species based on its life history & interactions.

Ecosystem Interactions



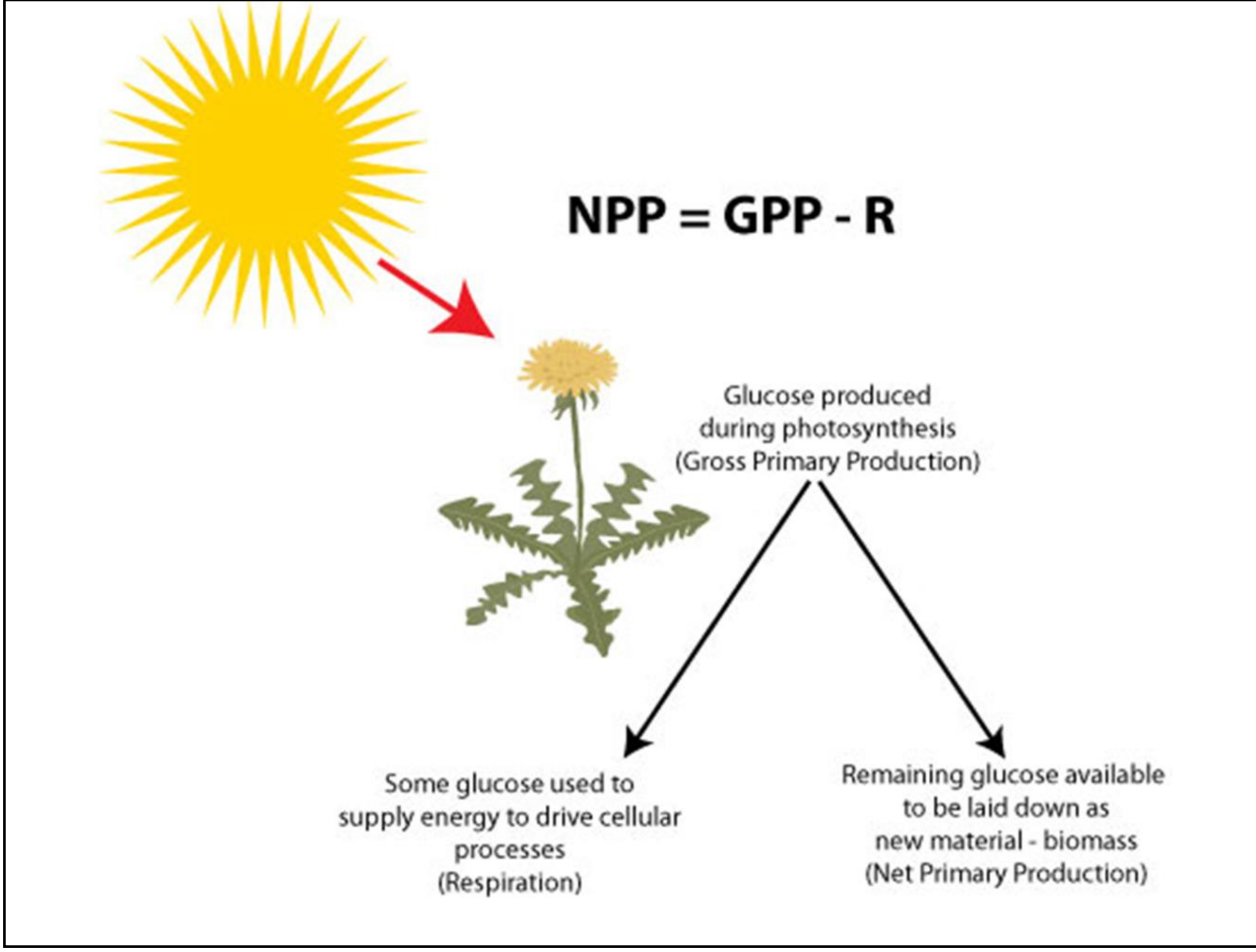
Interactions between organisms and their environments results in the movement of matter & energy

-**Energy flows through ecosystems**

-**Matter is recycled through ecosystems**

Primary Production

- Amount of solar energy converted into usable chemical energy in a time period.
- Predicts/Models the health of an ecosystem.
- Any change to primary productivity will lead to an amplified change in the rest of the ecosystem.



Producers: Produce chemical energy but also require it themselves for cellular respiration!

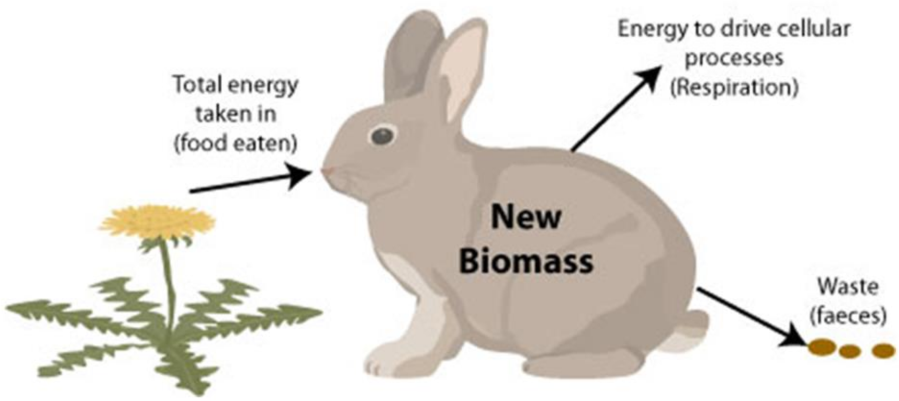
Gross PP = Total chemical energy produced

Net PP = GPP – R

Represents energy available to consumers and can be used to partially predict 'K' for a population

Secondary Production

Amount of consumers' food used towards their own body mass.



Plant has 200 J energy

Caterpillar eats plant

100 J of plant cannot be metabolized and is elimintated.

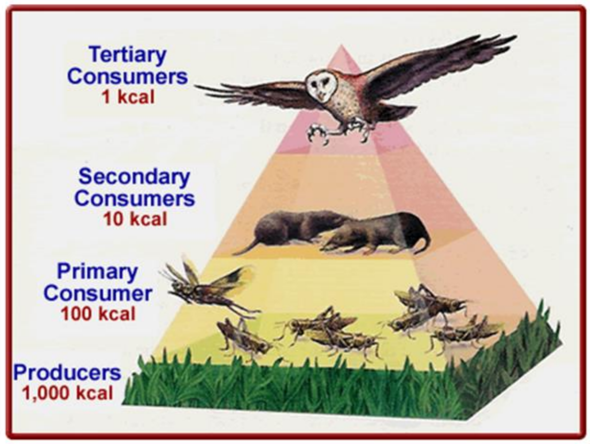
67 J is used for cellular respiration

This leaves 33 J (17%) energy contributing to the caterpillars body mass (growth).

Ecological Pyramids

1. Production Pyramid: Shows how much energy is in each trophic level.

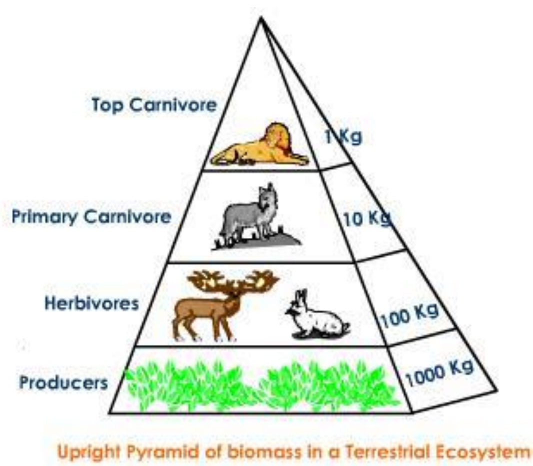
- About **10%** of **energy** in one trophic level is transferred to the next.



Ecological Pyramids

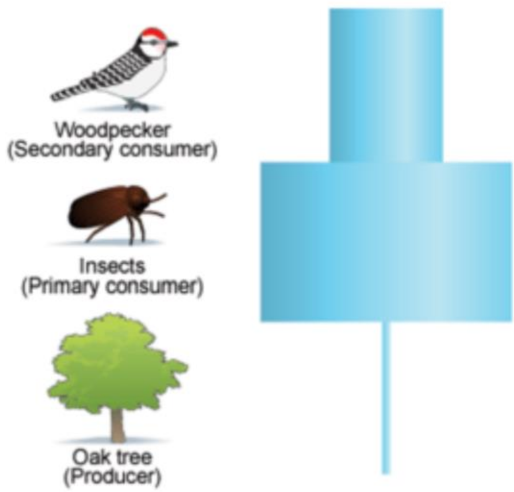
2. Biomass Pyramid: Shows the total amount of living material in a trophic level.

- Represents the potential amount of food for the next trophic level.



Ecological Pyramids

3. Pyramid of Numbers: Shows how many individuals are in each level.



Explain the difference in appearance of this model with the other 2 and explain why the shape is different. Would the shape always be like this?

Ecosystem Changes

- The distribution and abundance of populations depends on all the interactions among them along with environmental changes.
  - Too many lion prides in an area leads to intense competition.
  - Succession in communities leads some species to be replaced by others.

Primary Succession:

Secondary Succession:

Loss of Species

1. Invasive species
   - –Outcompete native species
   - –Introduced by humans either accidentally or on purpose

Kudzu: Introduced from Japan to Philadelphia

–Spreading 150,000 acres each year!

–Shades trees/shrubs

–No natural herbivores to limit growth

2. Habitat Disturbance/Destruction

- Forest Logging
- Gold Mining
- Construction
- Military Actions
- Oil Drilling

3. Climate Change

- Global Warming & Polar Bears
- Organism reproductive cycles changing